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HEAT CAPACITY RESULTS FOR AMMONIUM NITRATE AND PHASE STABILIZED AMMONIUM NITRATE FROM DSC MEASUREMENTS

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HEAT CAPACITY RESULTS FOR AMMONIUM NITRATE AND PHASE STABILIZED AMMONIUM NITRATE FROM DSC MEASUREMENTS

D.E.G. Jones* and P.P. Lee**

SUMMARY

A differential scanning calorimeter (DSC) has been set up to measure heat capacity, C_p. The performance of the DSC has been tested with sapphire and benzoic acid standards. C_p has been determined for ammonium nitrate (AN) and AN phase stabilized with KNO_3, CuO and NiO. The C_p values for AN have been compared with literature results and those for the phase stabilized AN have been compared with earlier DSC results. Results for AN and the AN composites have been discussed in terms of the phase transitions.

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Keywords: DSC, heat capacity, C_p, sapphire, benzoic acid, ammonium nitrate, phase stabilized ammonium nitrate, potassium nitrate, copper oxide, nickel oxide

CAPACITÉS THERMIQUES DU NITRATE D'AMMONIUM ET DU NITRATE D'AMMONIUM STABILISÉ EN PHASE OBTENUES À PARTIR DE MESURES DE CDB

D.E.G. Jones* et P.P. Lee**

SOMMAIRE

On a monté un calorimètre différentiel à balayage (CDB) pour mesurer la capacité thermique C_p. La performance du CDB a été éprouvée avec des étalons de saphir et d'acide benzoïque. On a déterminé C_p pour le nitrate d'ammonium (NA) et pour une phase de NA stabilisée avec du KNO_3, du CuO et du NiO. Les valeurs de C_p obtenues pour le NA ont été comparées avec les résultats rapportés dans la documentation, et les résultats obtenus avec la phase stabilisée de NA, avec des résultats antérieurs obtenus au CDB. Les résultats pour le NA et ses composés ont été analysés relativement aux transitions de phase.

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Mots clés : CDB, capacité thermique, C_p, saphir, acide benzoïque, nitrate d'ammonium, nitrate d'ammonium stabilisé en phase, nitrate de potassium, oxyde de cuivre, oxyde de nickel.

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INTRODUCTION

Ammonium nitrate is the base material for most commercial explosives and is also being used as the oxidizer in propellants. It is well established that AN undergoes phase transitions in the course of a thermal event (1) and these transitions are accompanied by large volume changes which deleteriously affect the mechanical properties of AN in a pyrotechnic mixture. These phase transitions are dependant on both the moisture content and the previous thermal history of the AN (2).

Use of additives to "phase stabilize" AN is well known (3). These additives alter the phase transitions and thermal patterns quite dramatically (4).

Heat capacity, ($C_p = (\delta H/\delta T)_p$) measurements are very sensitive to phase transitions since relatively large values of δH are involved for very small δT. DSC has been used extensively to measure C_p (5) (6) (7), in general, and, in particular, for AN (8) (9) (10) and some mixtures containing AN (11). Additionally, thermal analysis studies on AN phase stabilized with KNO_3, CuO and NiO have been reported (12).

EXPERIMENTAL

MATERIALS

High purity (99.99 mass %) indium and tin were supplied with the DSC and originated from the National Bureau of Standards (NBS), Washington, D.C. These materials were used for temperature calibration of the DSC.

Standard Reference Material 720 sapphire ($A1_2O_3$) of the NBS (13) was also supplied with the DSC and was used for energy flow calibration of the DSC and as a standard for C_p results.

Benzoic acid was also used as a standard for C_p results (14) and was NBS standard reference material donated by Dr. Y. P. Handa of the National Research Council (NRC).

ACS grade AN was supplied by Fisher and samples of AN phase stabilized with respectively, 7% by mass KNO_3, 5% by mass CuO and 3.5% by mass NiO were supplied by the Defence Research Establishment Valcartier.

DSC

The equipment used was a DuPont 9900 system, consisting of a Texas Instruments (TI) PC with a dedicated DuPont operating system, disk data storage, module interface, plotter and printer. The 910 DSC (15) was controlled by the computer with commercial software through the module interface.

Use of the 9900 system to measure C_p has been described in a thermal analysis applications memo from DuPont (16), and in the literature (17). Our system is not temperature controlled, hence the measurements are limited to those above room temperature, the exact lower temperature limit being determined by trial and error.

Temperature calibration of the DSC was carried out using the indium and tin described above. The NBS sapphire was used for energy flow calibration. All of the DSC measurements were done using a rate of temperature increase, B = 10 K/min.

Data files for the empty pan and sample (or reference material) in the DuPont operating system were converted to binary files using DuPont commercial software. A Fortran code (Appendix A) was written to convert the binary files to ASCII files and, additionally, to calculate C_p from

$$C_p/\mathrm{J\ g^{-1}\ K^{-1}} = E(\Delta W/\mathrm{J\ s})(60/\mathrm{s/min})(1000/\mathrm{mg/g})/((m/\mathrm{g})(B/\mathrm{K/min})) \qquad [1]$$

where E is the cell constant, ΔW is the energy flow and m is the sample mass.

A sample ASCII file is included in Appendix B. This file includes the basic run information from the DSC and a table of time, temperature and energy flow data. Results for pure materials were converted to J mol^{-1} K^{-1} by multiplying results obtained from [1] by the molar mass of the material.

The batch file included in Appendix C incorporates the entire process of data file conversion and C_p calculation and this file has been loaded onto the TI PC.

Matching of the empty pan and sample (or reference) temperatures in the ASCII files was done by trial and error with the aim of balancing, respectively, the desire for the maximum amount of data with the desire for the minimum ΔT. In general, the value of ΔT chosen was 0.02 K.

Appendix D lists an example of the output file obtained from running the batch file in Appendix C (incorporating the Fortran code in Appendix B) on the ASCII data file in Appendix B.

MEASUREMENTS ON STANDARD REFERENCE MATERIALS

Several sets of measurements were made for each of the standard reference materials, sapphire and benzoic acid. Comparison of the results from these measurements with published results (13) (14) is included below.

(i) Sapphire

Figures 1 to 5 depict the C_p results obtained for sapphire compared with the results obtained by fitting the experimental data to

$$C_p/\mathrm{J\ mol^{-1}\ K^{-1}} = A + B\ T/K \qquad [2]$$

Table 1 gives a comparison of the regression coefficients A and B and the correlation coefficient R^2 for the five runs done for sapphire. The fitted C_p results are compared with published data (13) in Table 2.

In Figure 6, the combined data from all the runs are compared with the published results. It is noted that the C_p results in the literature are not linear over the temperature range of interest (Figure 7), but the scatter in our experimental data precludes any attempt to fit to a polynomial equation such as that in (13).

TABLE 1

REGRESSION PARAMETERS IN [2] FOR SAPPHIRE

Run	A	Standard Error in C_p/J mol^{-1} K^{-1}	B	10^4 Standard Error in B	R^2
71	53.284	0.4	0.10103	2.5	0.982
73	54.966	0.4	0.10444	2.6	0.983
78	51.335	0.4	0.10778	2.6	0.989
82	48.888	0.5	0.10998	6.8	0.984
88	52.007	0.4	0.10199	4.6	0.984

TABLE 2

COMPARISON OF EXPERIMENTAL AND LITERATURE C_p RESULTS FOR SAPPHIRE

Temperature/K	Heat Capacity /J mol^{-1} K^{-1} This work	 Reference (13)
320	85.2	83.5
325	85.8	84.4
330	86.4	85.4
335	86.9	86.3
340	87.5	87.2
345	88.0	88.0
350	88.6	88.8
355	89.2	89.7
360	89.8	90.5
365	90.3	91.2
370	90.9	92.0
375	91.4	92.7
380	92.0	93.4
385	92.6	94.1
390	93.1	94.8
395	93.7	95.4
400	94.3	96.1
405	94.8	96.7
410	95.4	97.3
415	95.9	97.9
420	96.5	98.5
425	97.1	99.1
430	97.6	99.6
435	98.2	100.2
440	98.8	100.7

All runs show the distortion in C_p at T ≈ 395 K and it appears that this distortion is statistically significant although its source is unknown. Preheating "to 1000 °C in air prior to heat capacity measurements below 350 K" has been recommended (13).

In general, agreement with the literature results is better than ±3%, the expected limit of precision of C_p measurements from DSC (7).

(ii) Benzoic Acid

Figures 8 to 10 show the C_p data obtained for benzoic acid compared with the results obtained by fitting C_p to [2]. Table 3 gives a comparison of the regression coefficients A and B and the correlation coefficient R^2 for the three runs. The fitted results are compared with the published results (14) in Table 4. In Figure 11, the combined data for all three runs are compared with the published results. Finally, Figure 12 gives the experimental results for C_p of benzoic acid over the temperature range studied, including the melting transition point and the subsequent behaviour of the liquid.

TABLE 3

REGRESSION PARAMETERS IN [2] FOR BENZOIC ACID

Run	A	Standard Error in C_p/J mol^{-1} K^{-1}	B	10^3 Standard Error in B	R^2
80	28.731	0.8	0.4067	3.1	0.980
88	32.013	0.9	0.3903	3.9	0.973
90	31.543	1.2	0.3738	4.3	0.946

TABLE 4

COMPARISON OF EXPERIMENTAL AND LITERATURE C_p RESULTS FOR BENZOIC ACID

	Heat Capacity /J mol^{-1} K^{-1}	
Temperature/K	This work	Reference (14)
330	161	162
332	162	163
334	163	164
336	164	164
338	165	165
340	166	166
342	167	167
344	168	168
346	169	169
348	170	170
350	171	171
352	171	172
354	172	173
356	173	174
358	174	175
360	175	176
362	176	177
364	177	178
366	178	179
368	179	180
370	180	180
372	181	181
374	182	182
376	182	183
378	183	184
380	184	185
382	185	186
384	186	187
386	187	188
388	188	189
390	189	191

RESULTS AND DISCUSSION

AMMONIUM NITRATE (AN)

Figures 13 to 15 show, respectively, the C_p results determined for the three phase transitions observed for AN over the temperature range 325 to 430 K. These phase transitions are assumed to correspond to IV to II, III to II and II to I, respectively (12). The observed transition temperatures are compared with those obtained from earlier calorimetric studies (9) and from DSC experiments in this laboratory (12), in Table 5. It is apparent that the transition assigned to III to II occurs at a temperature significantly higher than that of the earlier studies. In contrast with these studies, there is no evidence in this work of any phase transition in the region from 350 to 370 K as can be seen from Figure 16, in which changes are within the limits of precision in C_p and are believed to reflect the instrumental "noise".

In the region 345 to 385 K, C_p for AN remains constant at 147 ± 2 J mol^{-1} K^{-1}. With the assumption that the observed transitions correspond to IV to II, III to II and II to I, the values of ΔH and ΔS for these transitions can be determined from

$$\Delta H = \int_{T_1}^{T_2} C_p dT \qquad [3]$$

and

$$\Delta S = \int_{T_1}^{T_2} C_p dT/T \qquad [4]$$

The integrations in [3] and [4] correspond to the areas under the curves in Figures 13 to 15 and these were determined numerically by using the trapezoidal rule on the data file generated from the code in Appendix A. The results are listed in Table 6, where the errors reflect both the combined uncertainty in selection of T_1 and T_2 and in the truncation error arising from use of the trapezoid rule.

TABLE 5

TRANSITION TEMPERATURES FOR PHASE TRANSITIONS OF AN

	TEMPERATURE/K		
PHASE TRANSITION	EXPERIMENTAL	REFERENCE (9)	REFERENCE (12)
IV to II	327	324	327
III to II	388	357	364
II to I	400	399	401

TABLE 6

THERMODYNAMIC DATA FOR PHASE TRANSITIONS OF AN

	ΔH/kJ mol^{-1}		ΔS/J mol^{-1} K^{-1}		
Phase Transition	Experimental	Literature	Experimental	Literature	% ΔV[b]
IV to II	3.2 ± 0.4	-	10 ± 1	-	-2.9
IV to III	-	1.8[b]	-	-	+3.6
III to II	1.3 ± 0.2	1.3[b]	3.3 ± 0.4	-	-1.3
II to I	7 ± 1	4.4[a] 4.2[b] 4.4[c]	18 ± 2	11.1[c]	+2.1

[a] Reference 18

[b] Reference 4

[c] Reference 9

PHASE STABILIZED AN

Figures 17 to 24 show the various transition points for AN + KNO_3, AN + CuO and AN + NiO. Table 7 gives the thermodynamic data determined in the same manner as described for AN.

AN + KNO_3

From Figure 17 it appears that there is a transition near 320 K, followed by a small exothermic change. However, these changes occur very close to the low temperature limit of the DSC thus leaving their interpretation open to considerable uncertainty. Repetition of these measurements will be undertaken once temperature control has been installed on the DSC.

The peaks in Figure 18 are assigned respectively to the IV to II, II to I and I to melting transitions. KNO_3 forms a mixed salt with AN but there is no evidence in this work for the presence of phase III as has been previously suggested (12).

TABLE 7

THERMODYNAMIC DATA FOR PHASE STABILIZED AN

Material	Peak	T/K	$\Delta H / J\ g^{-1}$	$\Delta S / J\ g^{-1}\ K^{-1}$
$AN+KNO_3$	1	388	49	0.12
	2	401	63	0.16
	3	427	99	0.23
AN+CuO	1	329	44	0.13
	2	385	55	0.14
	3	400	130	0.32
AN+ NiO	1	328	39	0.12
	2	395	100	0.25

AN + CuO

The transition shown in Figure 19 has been assigned to the transition IV to II, although the distorted shape of this peak suggests there may also be some IV to III transition taking place. The small peak in Figure 20 supports the presence of phase III and has been assigned to the transition III to II. The transition near 385 K (Figure 21) has not been observed in earlier DSC studies (12)(19). This transition is believed to correspond to the start of the solid phase reaction between CuO and AN (20). The third peak in Figure 21 has been assigned to the transition II to I. It is suggested that the shoulder on this peak arises as a result of the second step in the reaction forming the copper diamine complex (20).

AN + NiO

The peak at 328 K is ascribed to the transition IV to II. Once again the distorted nature of this peak and the small "bump" at the tail of this peak (Figure 23) suggest the presence of phase III. The results beyond 380 K obtained for this system differ significantly from those obtained for the AN + CuO system discussed earlier. The peak at 395 K has been assigned to the II to I transition. It is suggested that the overlapping peaks arise from (a) solid phase reaction to form the diamine complex (in one step in contrast with AN and CuO system) and (b) the transition I to melt. In an earlier report (12) a different explanation was given for the transition near 410 K.

CONCLUSIONS

The results presented in this report for sapphire and benzoic acid have demonstrated that the DSC is capable of determining C_p with a precision of less than ± 3%. Further, comparison of these results with those from the literature suggests that the DSC is capable of yielding an accuracy of less than 3% in C_p values.

The possiblity of detecting transitions is also demonstrated from the results for benzoic acid, although both the precision and accuracy of information derived from these transitions may be limited and dependent on B.

Transition temperatures determined for AN are generally comparable with those found in the literature. The following exceptions are noted: (1) no transition was observed between 350 and 370 K and (ii) the peak at 388 K was assigned to the III to II transition. Such exceptions are thought to be dependent on the history of the AN being studied. Thermodynamic information was derived for the assigned transitions.

Similarly, thermodynamic information was determined for the assigned transitions of the phase stabilized material. For the AN + KNO_3 system, only the crystallographic phase transitions IV to II and II to I were detected and the values of ΔH and ΔS were calculated for these transitions. There was evidence for the IV to III transition as well as the IV to II transition, in the case of the AN + metal oxide systems. In addition to the II to I transition, transitions were detected above 385 K and it was suggested that they arose as a result of the solid state reactions between AN and the metal oxide.

In general, it is expected C_p studies using the DSC should be more sensitive than energy flow analysis in the endothermic region. For this reason, observations and conclusions from these studies may differ from those given in earlier DSC studies.

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APPENDIX A

```
      PROGRAM BIASCP
$DEBUG
$NOTRUNCATE
      IMPLICIT DOUBLE PRECISION (A-H,O-Z)
      DIMENSION TE(4200),EMWATT(4200)
      DIMENSION TS(4200),SMWATT(4200)
      DIMENSION TCP(3500),CP(3500),SIGCP(3500)
      CHARACTER*20 BEFILE,AEFILE,BSFILE,ASFILE,OFILE,YN*1
      DATA ONE,TEN,SIXTY,TCON/1.0D0,10.0D0,60.0D0,273.15D0/
 1000 WRITE(*,10)
   10 FORMAT(' INPUT NAMES OF BINARY AND ASCII EMPTY PAN FILES , ',/)
      WRITE(*,11)
   11 FORMAT(' BINARY AND ASCII SAMPLE FILES AND OUTPUT FILE  - ONE FILEN
     1AME PER LINE',/)
      READ(*,15) BEFILE,AEFILE,BSFILE,ASFILE,OFILE
   15 FORMAT(4(A,/),A)
      OPEN(4,FILE=OFILE,STATUS='UNKNOWN')
      CALL FILEXIST(7,BEFILE,AEFILE)
      CALL FILEXIST(8,BSFILE,ASFILE)
   20 REWIND 8
      KE = 0
      KS = 0
      READ(8,50) EMASS,IBETA
      IF (IBETA.EQ.0) IBETA = 10
   50 FORMAT(///,5X,F8.4,/,6X,I3)
      REWIND 7
      READ(7,131)
  131 FORMAT(////////////////)
      READ(8,132)
  132 FORMAT(////////////)
      WRITE(*,100)
      GMM = ONE
  100 FORMAT(' INPUT LOWER AND UPPER TEMPERATURES IN CELSIUS',/)
      READ(*,*) TL,TU
      WRITE(*,101)
  101 FORMAT(' DO YOU WANT Cp CALCULATED PER GRAM Y OR N')
      READ(*,65) YN
      IF (YN.EQ.'Y'.OR.YN.EQ.'y') GO TO 130
      WRITE(*,102)
  102 FORMAT(' INPUT THE MOLAR MASS')
      READ(*,*) GMM
  130 DO 200 N = 7 , 8
  150 READ(N,160) TIME,T,XMWATT
  160 FORMAT(1X,3E12.5)
```

```
C     PRINT *,TIME,T,XMWATT
      IF (T.LE.TL) GO TO 150
      IF (T.GE.TU) GO TO 200
      IF (N.EQ.7) THEN
        KE = KE + 1
        TE(KE) = T
        EMWATT(KE) = XMWATT
      ELSE
        KS = KS + 1
        TS(KS) = T
        SMWATT(KS) = XMWATT
      ENDIF
      GO TO 150
  200 CONTINUE
   28 WRITE(4,29) BSFILE,TL,TU
   29 FORMAT(//,' Heat Capacity Results From ',A13,' For ',F4.0,
     1' To ',F4.0,' #C',//)
      IF (GMM.GT.1.) THEN
      WRITE(4,30)
   30 FORMAT(10X,' Temperature/K   Heat Capacity/J/mol K',/)
      ELSE
      WRITE(4,31)
   31 FORMAT(10X,' Temperature/K   Heat Capacity/J/g K',/)
      ENDIF
      NSTART = 1
      NCP = 1
      DO 400 J = 1 , KE
      DO 500 N = NSTART , KS
      IF ((TS(N) - TE(J)).LT..02) GO TO 450
      NSTART = N
      GO TO 400
  450 IF(ABS(TE(J) - TS(N)).GT..02) GO TO 500
      TCP(NCP) = TS(N)
      Q = EMWATT(J) - SMWATT(N)
      CP(NCP) = Q*SIXTY*GMM/(FLOAT(IBETA)*EMASS)
      TCP(NCP) = TCP(NCP) + TCON
      WRITE(4,40) TCP(NCP),CP(NCP)
   40 FORMAT(13X,F7.3,12X,F8.3)
      NCP = NCP + 1
  500 CONTINUE
  400 CONTINUE
      WRITE(*,45)
   45 FORMAT(' DO YOU WANT TO FIT THE DATA Y OR N',/)
      READ(*,65) YN
  65 FORMAT(A)
     IF (YN.EQ.'N'.OR.YN.EQ.'n') GO TO 580
     WRITE(*,71)
  71 FORMAT(' INPUT THE TEMPERATURE INCREMENT FOR THE TABLE OF
FITTED V
    1ALUES OF Cp')
     READ(*,*) TINC
  70 OPEN(3,FILE='STATS',STATUS='UNKNOWN')
     WRITE(3,66) BSFILE,TL,TU
  66 FORMAT(//,' STATISTICS FOR FIT OF DATA FROM ',A13,' FOR ',F4.0,
    1' TO ',F4.0,'oC',/)
     M = 0
     CALL FIT(TCP,CP,NCP-1,SIGCP,0,A,B,SIGA,SIGB,CHI2,Q)
             IF (M.EQ.0) THEN
                     WRITE(3,'(1X,A)') 'Ignoring standard deviation'
             ELSE
                     WRITE(3,'(1X,A)') 'Including standard deviation'
             ENDIF
             WRITE(3,'(1X,T5,A,F9.6,T24,A,F9.6)') 'A = ',A,'Uncertainty: ',
    *                SIGA
             WRITE(3,'(1X,T5,A,F9.6,T24,A,F9.6)') 'B = ',B,'Uncertainty: ',
    *                SIGB
             WRITE(3,'(1X,T5,A,4X,E10.3)') 'Chi-squared: ',CHI2
             WRITE(3,'(1X,T5,A,F10.6)') 'Goodness-of-fit: ',Q
     OPEN(9,FILE='CPCALC',STATUS='UNKNOWN')
     WRITE(9,55) BSFILE,INT(TL),INT(TU)
  55 FORMAT(//,' CALCULATED VALUES OF Cp FOR ',A11,'FOR',I3,
    1'TO',I3,'oC',//)
     IF (GMM.GT.1.) THEN
     WRITE(9,30)
     ELSE
     WRITE(9,31)
     ENDIF
     TC = TCON + TL
     ITC = INT(TC)
     ITC = ITC/10
     TC = TEN*FLOAT(ITC)
     TU = TU + TCON
 550 CPC = A + B*TC
     WRITE(9,41) INT(TC),CPC
  41 FORMAT(16X,I3,12X,F4.1)
     TC = TC + TINC
     IF (TC.GT.TU) GO TO 580
     GO TO 550
 580 CONTINUE
```

```
      WRITE(*,581)
  581 FORMAT(' DO YOU WANT TO DO ANOTHER CALCULATION ON THIS DATA
FILE Y
     1 OR N',/)
      READ(*,582) YN
  582 FORMAT(A)
      IF (YN.EQ.'N'.OR.YN.EQ.'n') GO TO 590
  585 GO TO 20
  590 WRITE(*,600)
  600 FORMAT(' DO YOU WANT TO DO A CALCULATION ON ANOTHER DATA FILE
Y OR
     1 N',/)
      READ(*,610) YN
  610 FORMAT(A)
      IF (YN.EQ.'Y'.OR.YN.EQ.'y') GO TO 1000
      END
      SUBROUTINE FILEXIST(N,BFILE,AFILE)
      CHARACTER*20 BFILE,AFILE
      LOGICAL EXIST
      INQUIRE(FILE=AFILE,EXIST=EXIST)
      IF (EXIST) THEN
        OPEN(N,FILE=AFILE,STATUS='OLD')
      ELSE
        CALL TACONVRT(BFILE,AFILE,N)
      ENDIF
   10 RETURN
      END
      SUBROUTINE TACONVRT(IN,OUT,NUNIT)
      REAL DATA(10)
      LOGICAL FF
      INTEGER*2 LEN
      INTEGER*2 I
      CHARACTER*20 IN
      CHARACTER*20 OUT
      CHARACTER*1 LINE(132)
      CHARACTER*127 PARAM
      REAL SIZE
      CHARACTER*5 PSIZE
      CHARACTER*20 PSIZEA
      EQUIVALENCE (PARAM,LINE)
      EQUIVALENCE (PARAM,PSIZE)
      EQUIVALENCE (LINE(5),PSIZEA)
      CHARACTER*1 BYTE
      INTEGER*2 NCHANS
```

```
100  FORMAT('0TACONVRT -- Binary TA data file to ASCII Converter'/)
101  FORMAT(' 'A\)
102  FORMAT(A)
103  FORMAT(' '132A1)
104  FORMAT('-----------------------------------')
105  FORMAT(' '10E12.5)
106  FORMAT(' Size parameter block line found. Value is ',G10.2)

     OPEN(2,FILE=IN,ACCESS='SEQUENTIAL',FORM='BINARY',STATUS='OLD')

     OPEN(NUNIT,FILE=OUT,ACCESS='SEQUENTIAL',FORM='FORMATTED',
    1  STATUS='UNKNOWN')

* Read the parameter block part of the file *
     FF=.FALSE.
     LEN=0
1000  CONTINUE
      READ(2,END=1001) BYTE
      IF (BYTE.EQ.CHAR(13)) THEN
*        * A <CR> signals the end of a PB line.
*          Discard the following <LF>, and write the line to the
*          output file *
        READ(2) BYTE
        WRITE(NUNIT,103) (LINE(I),I=1,LEN)

*        * Look for "SIZE" parameter block line, and convert to
*          floating point *
*        * Convert parameter name to uppercase *
        DO 10 I=1,4
          IF (LINE(I).LT.123 .AND. LINE(I).GT.96) THEN
            LINE(I)=CHAR(ICHAR(LINE(I))-32)
          ENDIF
10       CONTINUE
        IF (PSIZE.EQ.'SIZE ') THEN
          READ(2) SIZE
          WRITE(*,106) SIZE
        ENDIF

        LEN=0

      ELSEIF (BYTE.EQ.CHAR(12)) THEN
*        * A <FF> signals the end of the PB. The next byte is
*          the # of chans *
        READ(2) BYTE
        NCHANS=ICHAR(BYTE)
```

```
          FF=.TRUE.

        ELSE
*         * This character has no special significance, so just append
*           to the end of the current line *
          LEN=LEN+1
          LINE(LEN)=BYTE
        ENDIF

      IF (.NOT. FF) GOTO 1000

1001  CONTINUE
      WRITE(NUNIT,104)

*     Read the data part of the file. It consists of a stream of
*     bytes. Groups of 4 bytes constitute a real number in 8087
*     format. Each data point consists of "nchans" real numbers *
1010  CONTINUE
        READ(2,END=1011) (DATA(I),I=1,NCHANS)
        WRITE(NUNIT,105) (DATA(I),I=1,NCHANS)
      GOTO 1010

1011  CONTINUE
      RETURN
      END
      SUBROUTINE FIT(X,Y,NDATA,SIG,MWT,A,B,SIGA,SIGB,CHI2,Q)
      IMPLICIT DOUBLE PRECISION (A-H,O-Z)
      DIMENSION X(NDATA),Y(NDATA),SIG(NDATA)
      DATA ZERO,HALF,ONE/0.0D0,0.5D0,1.0D0/
      SX = ZERO
      SY = ZERO
      ST2 = ZERO
      B = ZERO
C       PRINT *,' NDATA = ',NDATA
      IF(MWT.NE.0) THEN
        SS = ZERO
        DO 11 I=1,NDATA
          WT = ONE/(SIG(I)**2)
          SS=SS+WT
          SX=SX+X(I)*WT
          SY=SY+Y(I)*WT
11      CONTINUE
      ELSE
        DO 12 I=1,NDATA
C         PRINT *,' X = ',X(I)
```

```
C          PRINT *,' Y = ',Y(I)
          SX=SX+X(I)
          SY=SY+Y(I)
12       CONTINUE
        SS=FLOAT(NDATA)
      ENDIF
      SXOSS=SX/SS
      IF(MWT.NE.0) THEN
        DO 13 I=1,NDATA
          T=(X(I)-SXOSS)/SIG(I)
          ST2=ST2+T*T
          B=B+T*Y(I)/SIG(I)
13       CONTINUE
      ELSE
        DO 14 I=1,NDATA
          T=X(I)-SXOSS
          ST2=ST2+T*T
          B=B+T*Y(I)
14       CONTINUE
      ENDIF
      B=B/ST2
      A=(SY-SX*B)/SS
      SIGA=DSQRT((ONE + SX*SX/(SS*ST2))/SS)
      SIGB=DSQRT(ONE/ST2)
      CHI2 = ZERO
      IF(MWT.EQ.0) THEN
        DO 15 I=1,NDATA
          CHI2=CHI2+(Y(I)-A-B*X(I))**2
15       CONTINUE
        Q = ONE
        FNDATA2 = FLOAT(NDATA - 2)
        SIGDAT=DSQRT(CHI2/FNDATA2)
        SIGA=SIGA*SIGDAT
        SIGB=SIGB*SIGDAT
      ELSE
        DO 16 I=1,NDATA
          CHI2=CHI2+((Y(I)-A-B*X(I))/SIG(I))**2
16       CONTINUE
        FNDATA2 = FLOAT(NDATA - 2)
        Q = GAMMQ(HALF*FNDATA2,HALF*CHI2)
      ENDIF
      RETURN
      END
      FUNCTION GAMMQ(A,X)
      IMPLICIT DOUBLE PRECISION (A-H,O-Z)
      DATA ZERO,ONE/0.0D0,1.0D0/
      IF(X.LT.ZERO.OR.A.LE.ZERO) PAUSE
      IF(X.LT.(A+ONE))THEN
        CALL GSER(GAMSER,A,X,GLN)
        GAMMQ = ONE - GAMSER
      ELSE
        CALL GCF(GAMMCF,A,X,GLN)
        GAMMQ=GAMMCF
      ENDIF
      RETURN
      END
      SUBROUTINE GSER(GAMSER,A,X,GLN)
      IMPLICIT DOUBLE PRECISION (A-H,O-Z)
      PARAMETER (ITMAX=100,EPS=3.E-7)
      DATA ZERO,ONE/0.0D0,1.0D0/
      GLN=GAMMLN(A)
      IF(X.LE.ZERO)THEN
        IF(X.LT.ZERO)PAUSE
        GAMSER = ZERO
        RETURN
      ENDIF
      AP=A
      SUM = ONE/A
      DEL=SUM
      DO 11 N=1,ITMAX
        AP = AP + ONE
        DEL=DEL*X/AP
        SUM=SUM+DEL
        IF(DABS(DEL).LT.DABS(SUM)*EPS)GO TO 1
11    CONTINUE
      PAUSE 'A too large, ITMAX too small'
1     GAMSER=SUM*DEXP(-X+A*DLOG(X)-GLN)
      RETURN
      END
      SUBROUTINE GCF(GAMMCF,A,X,GLN)
      IMPLICIT DOUBLE PRECISION (A-H,O-Z)
      PARAMETER (ITMAX=100,EPS=3.E-7)
      DATA ZERO,ONE/0.0D0,1.0D0/
      GLN=GAMMLN(A)
      GOLD = ZERO
      A0 = ONE
      A1=X
      B0 = ZERO
      B1 = ONE
      FAC = ONE
      DO 11 N=1,ITMAX
        AN=FLOAT(N)
        ANA=AN-A
        A0=(A1+A0*ANA)*FAC
        B0=(B1+B0*ANA)*FAC
        ANF=AN*FAC
        A1=X*A0+ANF*A1
        B1=X*B0+ANF*B1
        IF(A1.NE.ZERO)THEN
          FAC = ONE/A1
          G=B1*FAC
          IF(DABS((G-GOLD)/G).LT.EPS)GO TO 1
          GOLD=G
        ENDIF
11     CONTINUE
      PAUSE 'A too large, ITMAX too small'
1      GAMMCF=DEXP(-X+A*DLOG(X)-GLN)*G
      RETURN
      END
      FUNCTION GAMMLN(XX)
      IMPLICIT DOUBLE PRECISION (A-H,O-Z)
      DIMENSION COF(6)
      DATA COF,STP/76.18009173D0,-86.50532033D0,24.01409822D0,
     *    -1.231739516D0,.120858003D-2,-.536382D-5,2.50662827465D0/
      DATA HALF,ONE,FPF/0.5D0,1.0D0,5.5D0/
      X=XX-ONE
      TMP=X+FPF
      TMP=(X+HALF)*DLOG(TMP)-TMP
      SER=ONE
      DO 11 J=1,6
        X=X+ONE
        SER=SER+COF(J)/X
11     CONTINUE
      GAMMLN=TMP+DLOG(STP*SER)
      RETURN
      END
```

APPENDIX B

```
Run 469
Module DSC
Sample AL2O3
Size 30.5330 mg
od CP
Operator P.LEE
Comment N2 50ML/MIN, HERMETIC AL PAN
Nsig 3
Sig1 Time (min)
Sig2 Temperature (#C)
Sig3 Heat Flow (mW)
Kcell 1.2894
Calib -14.53
Date 06/07/89
Time 10:23
-------------------------------------
  .00000E+00  .47569E+02 -.19481E+01
  .33333E-02  .47578E+02 -.19389E+01
  .66667E-02  .47588E+02 -.19297E+01
  .10000E-01  .47597E+02 -.19224E+01
  .13333E-01  .47607E+02 -.19169E+01
  .16667E-01  .47617E+02 -.19077E+01
  .20000E-01  .47617E+02 -.19004E+01
  .23333E-01  .47626E+02 -.18949E+01
  .26667E-01  .47636E+02 -.18875E+01
  .30000E-01  .47645E+02 -.18802E+01
  .33333E-01  .47655E+02 -.18728E+01
  .36667E-01  .47664E+02 -.18655E+01
  .40000E-01  .47664E+02 -.18563E+01
  .43333E-01  .47684E+02 -.18490E+01
  .46667E-01  .47684E+02 -.18416E+01
  .50000E-01  .47693E+02 -.18343E+01
  .53333E-01  .47703E+02 -.18269E+01
  .56667E-01  .47712E+02 -.18196E+01
  .60000E-01  .47712E+02 -.18141E+01
  .63333E-01  .47722E+02 -.18067E+01
  .66667E-01  .47732E+02 -.17994E+01
  .70000E-01  .47732E+02 -.17902E+01
  .73333E-01  .47741E+02 -.17847E+01
  .76667E-01  .47751E+02 -.17755E+01
  .80000E-01  .47751E+02 -.17663E+01
  .83333E-01  .47760E+02 -.17572E+01
  .86667E-01  .47770E+02 -.17498E+01
  .90000E-01  .47780E+02 -.17425E+01
```

```
 .93333E-01  .47780E+02 -.17333E+01
 .96667E-01  .47780E+02 -.17259E+01
 .10000E+00  .47789E+02 -.17204E+01
 .10333E+00  .47799E+02 -.17094E+01
 .10667E+00  .47808E+02 -.17021E+01
 .11000E+00  .47799E+02 -.16929E+01
 .11333E+00  .47808E+02 -.16855E+01
 .11667E+00  .47818E+02 -.16764E+01
 .12000E+00  .47818E+02 -.16672E+01
 .12333E+00  .47828E+02 -.16580E+01
 .12667E+00  .47828E+02 -.16488E+01
 .13000E+00  .47837E+02 -.16396E+01
 .13333E+00  .47837E+02 -.16323E+01
 .13667E+00  .47847E+02 -.16213E+01
 .14000E+00  .47856E+02 -.16121E+01
 .14333E+00  .47856E+02 -.16029E+01
 .14667E+00  .47856E+02 -.15937E+01
 .15000E+00  .47866E+02 -.15827E+01
 .15333E+00  .47866E+02 -.15735E+01
 .15667E+00  .47866E+02 -.15644E+01
 .16000E+00  .47876E+02 -.15552E+01
 .16333E+00  .47885E+02 -.15442E+01
 .16667E+00  .47885E+02 -.15331E+01
 .17000E+00  .47895E+02 -.15221E+01
 .17333E+00  .47895E+02 -.15130E+01
 .17667E+00  .47895E+02 -.15038E+01
 .18000E+00  .47904E+02 -.14928E+01
 .18333E+00  .47904E+02 -.14817E+01
 .18667E+00  .47914E+02 -.14726E+01
 .19000E+00  .47904E+02 -.14615E+01
 .19333E+00  .47904E+02 -.14524E+01
 .19667E+00  .47914E+02 -.14413E+01
 .20000E+00  .47924E+02 -.14322E+01
 .20333E+00  .47914E+02 -.14211E+01
 .20667E+00  .47924E+02 -.14120E+01
 .21000E+00  .47933E+02 -.13991E+01
 .21333E+00  .47924E+02 -.13881E+01
 .21667E+00  .47933E+02 -.13789E+01
 .22000E+00  .47933E+02 -.13679E+01
 .22333E+00  .47933E+02 -.13587E+01
 .22667E+00  .47943E+02 -.13459E+01
 .23000E+00  .47943E+02 -.13348E+01
 .23333E+00  .47943E+02 -.13238E+01
 .23667E+00  .47952E+02 -.13128E+01
 .24000E+00  .47943E+02 -.13036E+01
```

```
.24333E+00  .47952E+02 -.12926E+01
.24667E+00  .47952E+02 -.12834E+01
.25000E+00  .47952E+02 -.12724E+01
.25333E+00  .47962E+02 -.12614E+01
.25667E+00  .47962E+02 -.12522E+01
.26000E+00  .47962E+02 -.12412E+01
.26333E+00  .47972E+02 -.12302E+01
.26667E+00  .47972E+02 -.12192E+01
.27000E+00  .47972E+02 -.12082E+01
.27333E+00  .47972E+02 -.11971E+01
.27667E+00  .47972E+02 -.11880E+01
.28000E+00  .47981E+02 -.11751E+01
.28333E+00  .47981E+02 -.11641E+01
.28667E+00  .47981E+02 -.11531E+01
.29000E+00  .47972E+02 -.11439E+01
.29333E+00  .47981E+02 -.11310E+01
.29667E+00  .47981E+02 -.11200E+01
.30000E+00  .47981E+02 -.11090E+01
.30333E+00  .47991E+02 -.10998E+01
.30667E+00  .47981E+02 -.10888E+01
.31000E+00  .47991E+02 -.10796E+01
.31333E+00  .47991E+02 -.10686E+01
.31667E+00  .47981E+02 -.10576E+01
.32000E+00  .47991E+02 -.10484E+01
.32333E+00  .47991E+02 -.10392E+01
.32667E+00  .47991E+02 -.10282E+01
.33000E+00  .47981E+02 -.10172E+01
.33333E+00  .47991E+02 -.10062E+01
.33667E+00  .48000E+02 -.99517E+00
.34000E+00  .47991E+02 -.98599E+00
.34333E+00  .47991E+02 -.97681E+00
.34667E+00  .47991E+02 -.96396E+00
.35000E+00  .47991E+02 -.95661E+00
.35333E+00  .48000E+02 -.94559E+00
.35667E+00  .48000E+02 -.93641E+00
.36000E+00  .47991E+02 -.92356E+00
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.36667E+00  .48000E+02 -.90336E+00
.37000E+00  .47991E+02 -.89418E+00
.37333E+00  .48000E+02 -.88500E+00
.37667E+00  .47991E+02 -.87582E+00
.38000E+00  .47991E+02 -.86481E+00
.38333E+00  .48000E+02 -.85746E+00
.38667E+00  .47991E+02 -.84644E+00
.39000E+00  .48000E+02 -.83543E+00
```

```
.39333E+00  .47991E+02 -.82625E+00
.39667E+00  .48000E+02 -.81707E+00
.40000E+00  .47991E+02 -.80789E+00
.40333E+00  .47991E+02 -.79871E+00
.40667E+00  .48000E+02 -.78769E+00
.41000E+00  .48000E+02 -.77851E+00
.41333E+00  .47991E+02 -.77116E+00
.41667E+00  .48000E+02 -.76382E+00
.42000E+00  .47991E+02 -.75280E+00
.42333E+00  .47991E+02 -.74546E+00
.42667E+00  .48000E+02 -.73444E+00
.43000E+00  .47991E+02 -.72526E+00
.43333E+00  .47991E+02 -.71608E+00
.43667E+00  .47991E+02 -.70690E+00
.44000E+00  .47991E+02 -.69772E+00
.44333E+00  .47991E+02 -.69038E+00
.44667E+00  .47991E+02 -.68120E+00
.45000E+00  .47991E+02 -.67201E+00
.45333E+00  .47991E+02 -.66283E+00
.45667E+00  .47991E+02 -.65549E+00
.46000E+00  .47981E+02 -.64815E+00
.46333E+00  .47981E+02 -.64080E+00
.46667E+00  .47991E+02 -.62978E+00
.47000E+00  .47981E+02 -.62060E+00
.47333E+00  .47991E+02 -.61326E+00
.47667E+00  .47981E+02 -.60408E+00
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.49667E+00  .47972E+02 -.55818E+00
.50000E+00  .47981E+02 -.54900E+00
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.53333E+00  .47962E+02 -.47188E+00
.53667E+00  .47972E+02 -.46453E+00
.54000E+00  .47952E+02 -.45719E+00
.54333E+00  .47952E+02 -.44985E+00
```

```
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.55000E+00  .47962E+02 -.43699E+00
.55333E+00  .47962E+02 -.42965E+00
.55667E+00  .47952E+02 -.42230E+00
.56000E+00  .47952E+02 -.41680E+00
.56333E+00  .47952E+02 -.40945E+00
.56667E+00  .47952E+02 -.40211E+00
.57000E+00  .47943E+02 -.39476E+00
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.58000E+00  .47943E+02 -.37640E+00
.58333E+00  .47943E+02 -.36906E+00
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.60333E+00  .47924E+02 -.33234E+00
.60667E+00  .47924E+02 -.32683E+00
.61000E+00  .47933E+02 -.31948E+00
.61333E+00  .47933E+02 -.31214E+00
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.62667E+00  .47914E+02 -.29010E+00
.63000E+00  .47914E+02 -.28276E+00
.63333E+00  .47914E+02 -.27725E+00
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.64000E+00  .47904E+02 -.26624E+00
.64333E+00  .47914E+02 -.26073E+00
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.65000E+00  .47895E+02 -.24971E+00
.65333E+00  .47904E+02 -.24420E+00
.65667E+00  .47895E+02 -.23686E+00
.66333E+00  .47895E+02 -.22768E+00
.66667E+00  .47885E+02 -.22033E+00
.67333E+00  .47895E+02 -.21115E+00
.67667E+00  .47885E+02 -.20564E+00
.68333E+00  .47885E+02 -.19646E+00
.68667E+00  .47876E+02 -.19095E+00
.69000E+00  .47876E+02 -.18545E+00
.69667E+00  .47876E+02 -.17627E+00
.70333E+00  .47866E+02 -.16892E+00
.70667E+00  .47866E+02 -.16341E+00
.71333E+00  .47856E+02 -.15423E+00
.72000E+00  .47856E+02 -.14322E+00
.72667E+00  .47856E+02 -.13587E+00
```

```
 .73333E+00  .47837E+02 -.12669E+00
 .73667E+00  .47847E+02 -.12118E+00
 .74333E+00  .47837E+02 -.11384E+00
 .74667E+00  .47837E+02 -.10833E+00
 .75333E+00  .47837E+02 -.10099E+00
 .76000E+00  .47828E+02 -.91805E-01
 .76333E+00  .47818E+02 -.86297E-01
 .77000E+00  .47828E+02 -.77116E-01
 .77667E+00  .47818E+02 -.67936E-01
 .78333E+00  .47818E+02 -.58755E-01
 .79000E+00  .47808E+02 -.51411E-01
 .79667E+00  .47808E+02 -.42230E-01
 .80333E+00  .47808E+02 -.33050E-01
 .80667E+00  .47808E+02 -.27542E-01
 .81000E+00  .47808E+02 -.22033E-01
 .81333E+00  .47808E+02 -.16525E-01
 .82000E+00  .47808E+02 -.91805E-02
 .82667E+00  .47799E+02 -.18361E-02
 .83000E+00  .47808E+02  .36722E-02
 .83667E+00  .47799E+02  .11017E-01
 .84333E+00  .47799E+02  .20197E-01
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 .85667E+00  .47799E+02  .34886E-01
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.23470E+02  .17914E+03 -.19993E+01
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.23477E+02  .17913E+03 -.19088E+01
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.23743E+02  .17889E+03  .20048E+00
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.31117E+02  .17866E+03 -.14542E+00
.31310E+02  .17865E+03 -.13953E+00
.31367E+02  .17865E+03 -.13363E+00
.31443E+02  .17864E+03 -.12773E+00
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.31713E+02  .17865E+03 -.15132E+00
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.31923E+02  .17865E+03 -.16311E+00
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.32843E+02  .17863E+03 -.14542E+00
.32920E+02  .17862E+03 -.13952E+00
```

APPENDIX C

```
REM THIS IS A BATCH FILE TO CALCULATE Cp FROM DSC TA FILES
PAUSE INSERT DISK WITH DSC FILES IN DRIVE A
TAGET A:DSC-.%1 BI-%1
TAGET A:DSC-%2 BI-%2
CPDSC %3 BI-%1 BI-%2
DEL BI*.*
IF NOT EXIST CPCALC GOTO ENDTAG
PAUSE TURN PRINTER ON
PRINT CPCALC
PRINT STATS
DEL CPCALC
DEL STATS
:ENDTAG
```

APPENDIX D

Heat Capacity Results From BI-AL2O3.71 For 50 To 170 °C

Temperature/K	Heat Capacity/J/mol K
323.155	38.848
323.184	39.473
323.232	40.209
323.261	40.908
323.328	42.125
323.415	43.559
323.443	44.186
323.482	44.848
323.520	45.511
323.558	46.175
323.597	46.837
323.626	47.499
323.664	48.199
323.702	48.898
323.741	49.526
323.789	50.188
323.817	50.815
323.856	51.477
323.894	52.066
323.933	52.767
323.971	53.356
324.009	54.019
324.048	54.645
324.096	55.271
324.125	55.935
324.163	56.524
324.201	57.151
324.240	57.776
324.278	58.441
324.316	58.994
324.355	59.619
324.393	60.171
324.432	60.836
324.479	61.352
324.518	61.977
324.556	62.568
324.595	63.158
324.643	63.711
324.681	64.263
324.719	64.853

324.748	65.444
324.796	65.960
324.834	66.511
324.873	67.065
324.911	67.545
324.950	68.098
324.988	68.651
325.036	69.168
325.065	69.682
325.113	70.199
325.151	70.679
325.189	71.194
325.228	71.675
325.266	72.155
325.305	72.670
325.333	73.114
325.381	73.593
325.420	74.036
325.458	74.478
325.487	74.884
325.525	75.402
325.573	75.808
325.602	76.250
325.640	76.693
325.669	77.060
325.708	77.503
325.746	77.872
325.794	78.278
325.823	78.685
325.871	79.054
325.909	79.460
325.938	79.830
325.976	80.161
326.015	80.494
326.053	80.864
326.101	81.159
326.130	81.565
326.168	81.899
326.216	82.158
326.245	82.527
326.283	82.895
326.312	83.118
326.360	83.414
326.437	84.005
326.475	84.301

326.504	84.595
326.542	84.854
326.581	85.150
326.619	85.373
326.657	85.631
326.686	85.852
326.734	86.112
326.773	86.335
326.801	86.557
326.840	86.742
326.888	87.000
326.916	87.185
326.955	87.371
326.993	87.519
327.022	87.705
327.060	87.964
327.089	88.149
327.137	88.261
327.166	88.445
327.204	88.558
327.243	88.743
327.281	88.891
327.310	89.076
327.348	89.187
327.377	89.337
327.415	89.522
327.454	89.634
327.492	89.745
327.521	89.855
327.559	89.967
327.598	90.115
327.636	90.191
327.665	90.303
327.703	90.377
327.742	90.453
327.770	90.527
327.809	90.601
327.847	90.640
327.876	90.677
327.914	90.788
327.943	90.864
327.981	90.901
328.020	90.940
328.049	90.978
328.077	91.052

328.116	91.053
328.154	91.128
328.192	91.093
328.221	91.203
328.260	91.131
328.298	91.207
328.327	91.281
328.356	91.208
328.394	91.246
328.432	91.210
328.461	91.248
328.499	91.249
328.528	91.213
328.567	91.178
328.595	91.216
328.643	91.217
328.663	91.180
328.701	91.183
328.739	91.146
328.768	91.147
328.806	91.185
328.835	91.113
328.874	90.966
328.912	90.966
328.931	90.931
328.970	90.968
329.008	90.971
329.037	90.934
329.075	90.936
329.104	90.863
329.142	90.826
329.171	90.754
329.199	90.718
329.237	90.683
329.275	90.647
329.313	90.647
329.342	90.538
329.371	90.502
329.409	90.393
329.437	90.284
329.466	90.248
329.513	90.174
329.551	90.101
329.580	90.028
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329.675	89.847
329.713	89.738
329.742	89.664
329.770	89.628
329.799	89.520
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329.865	89.412
329.894	89.375
329.932	89.340
329.970	89.229
329.999	89.120
330.027	89.084
330.056	89.012
330.094	88.865
330.132	88.829
330.161	88.757
330.189	88.683
330.227	88.611
330.265	88.502
330.294	88.464
330.322	88.355
330.360	88.356
330.389	88.283
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330.494	88.029
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330.551	87.919
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330.655	87.665
330.684	87.629
330.712	87.592
330.751	87.483
330.789	87.409
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330.950	87.194
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331.141	86.867
331.179	86.794
331.207	86.759
331.236	86.685
331.265	86.613
331.303	86.539
331.331	86.466
331.369	86.469
331.407	86.433
331.436	86.359
331.464	86.287
331.493	86.213
331.531	86.177
331.569	86.142
331.598	86.069
331.636	86.033
331.664	85.997
331.702	85.925
331.731	85.851
331.769	85.815
331.797	85.742
331.836	85.744
331.864	85.744
331.902	85.708
331.931	85.636
331.959	85.562
331.997	85.601
332.035	85.565
332.073	85.602
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332.131	85.567
332.159	85.458
332.197	85.459
332.235	85.460
332.273	85.387
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332.330	85.352
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332.492	85.245
332.530	85.172
332.559	85.173

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332.635	85.102
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332.768	85.032
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334.481	85.488
334.519	85.452
334.557	85.490
334.576	85.490
334.624	85.565
334.653	85.640
334.691	85.604
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334.757	85.680
334.786	85.644
334.824	85.719
334.852	85.757
334.891	85.758
334.929	85.796
334.957	85.834
334.995	85.872
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335.090	85.985
335.138	85.950
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335.205	85.988
335.233	85.989
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335.576	86.258
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335.709	86.409
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337.974	87.695
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338.212	87.886
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338.345	87.890
338.374	87.855
338.412	87.855
338.440	87.893
338.479	87.896
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338.545	87.898
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338.612	87.973
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338.669	87.975

338.707	87.977
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338.774	87.941
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338.840	87.942
338.888	87.981
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339.668	88.077
339.706	88.115
339.735	88.080
339.763	88.117
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339.839	88.120
339.868	88.122
339.906	88.160
339.935	88.122
339.973	88.161
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340.049	88.162
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340.106	88.203
340.144	88.203
340.173	88.167
340.211	88.167

340.249	88.205
340.277	88.206
340.306	88.208
340.344	88.209
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340.411	88.286
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340.477	88.286
340.515	88.213
340.544	88.252
340.582	88.252
340.610	88.254
340.648	88.254
340.677	88.293
340.715	88.256
340.744	88.257
340.782	88.222
340.820	88.222
340.858	88.260
340.886	88.224
340.924	88.226
340.953	88.191
340.991	88.229
341.020	88.192
341.058	88.194
341.086	88.230
341.124	88.269
341.153	88.233
341.191	88.233
341.229	88.272
341.267	88.274
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341.324	88.201
341.362	88.203
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341.466	88.279
341.495	88.317
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341.561	88.283
341.599	88.284
341.637	88.285
341.665	88.321
341.703	88.285
341.732	88.287

341.770	88.214
341.798	88.290
341.836	88.254
341.864	88.218
341.902	88.218
341.931	88.256
341.969	88.219
342.007	88.221
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342.063	88.223
342.111	88.151
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342.168	88.153
342.206	88.117
342.244	88.155
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342.300	88.118
342.348	88.120
342.367	88.084
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342.575	88.126
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342.784	88.171
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342.879	88.135
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342.983	88.102
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343.182	88.108
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343.656	88.233
343.694	88.235
343.722	88.197
343.760	88.199
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346.898	88.255
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349.732	88.724
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355.813	89.857
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355.889	89.899
355.927	89.901
355.956	89.864
355.994	89.866
356.032	89.868
356.061	89.868
356.099	89.833
356.127	89.833
356.165	89.835
356.194	89.873
356.232	89.875
356.270	89.878
356.299	89.878
356.327	89.843
356.365	89.881
356.403	89.883
356.432	89.883
356.470	89.885
356.508	89.848
356.536	89.887
356.575	89.890
356.613	89.890
356.641	89.855
356.670	89.855
356.708	89.895
356.736	89.895
356.774	89.897
356.803	89.898
356.841	89.900
356.870	89.900
356.908	89.902
356.936	89.940
356.974	89.942
357.012	89.944

357.041	89.945
357.079	89.947
357.108	89.910
357.146	89.912
357.174	89.912
357.212	89.914
357.250	89.879
357.279	89.879
357.317	89.919
357.345	89.920
357.374	89.958
357.412	89.922
357.441	89.924
357.488	89.926
357.517	89.964
357.545	90.002
357.583	90.004
357.621	90.006
357.650	89.969
357.688	89.970
357.717	89.971
357.755	89.898
357.783	89.936
357.821	89.900
357.850	89.902
357.888	89.978
357.916	89.942
357.945	89.944
357.983	89.945
358.021	89.946
358.059	89.985
358.088	89.986
358.126	89.988
358.154	89.989
358.192	89.991
358.221	89.993
358.259	89.994
358.297	89.995
358.326	89.995
358.364	89.997
358.392	89.999
358.421	89.963
358.459	89.964
358.487	89.965
358.526	89.967

358.554	90.006
358.592	90.006
358.630	89.970
358.668	89.973
358.697	90.011
358.725	89.975
358.763	89.977
358.792	89.977
358.830	89.979
358.859	89.942
358.897	89.943
358.935	90.021
358.963	89.948
358.992	89.985
359.030	89.987
359.059	89.950
359.106	90.028
359.125	90.028
359.163	90.066
359.201	90.031
359.230	90.033
359.277	90.033
359.296	90.035
359.344	89.999
359.363	89.999
359.401	90.002
359.439	90.040
359.487	90.043
359.515	90.082
359.534	90.120
359.572	90.120
359.601	90.122
359.639	90.160
359.667	90.162
359.705	90.200
359.743	90.240
359.781	90.167
359.809	90.167
359.838	90.206
359.876	90.207
359.904	90.245
359.942	90.171
359.980	90.248
360.008	90.250
360.046	90.214

360.075	90.214
360.113	90.217
360.141	90.217
360.179	90.257
360.217	90.332
360.245	90.334
360.283	90.335
360.321	90.299
360.350	90.301
360.388	90.266
360.416	90.266
360.444	90.304
360.482	90.269
360.520	90.307
360.558	90.309
360.587	90.347
360.615	90.349
360.653	90.350
360.681	90.425
360.719	90.390
360.748	90.392
360.786	90.392
360.824	90.394
360.861	90.397
360.890	90.397
360.928	90.436
360.947	90.398
360.985	90.400
361.023	90.402
361.061	90.403
361.089	90.443
361.127	90.443
361.155	90.481
361.193	90.484
361.222	90.448
361.260	90.448
361.288	90.449
361.326	90.452
361.364	90.491
361.402	90.491
361.430	90.531
361.468	90.569
361.497	90.571
361.534	90.534
361.572	90.536

361.601	90.501
361.639	90.576
361.667	90.614
361.705	90.617
361.734	90.655
361.771	90.731
361.800	90.695
361.828	90.695
361.866	90.697
361.904	90.773
361.942	90.738
361.970	90.738
361.999	90.740
362.037	90.742
362.075	90.742
362.113	90.783
362.141	90.783
362.170	90.785
362.207	90.786
362.245	90.788
362.274	90.826
362.302	90.826
362.340	90.790
362.378	90.904
362.416	90.906
362.444	90.906
362.473	90.908
362.511	90.911
362.539	90.911
362.577	90.913
362.615	90.876
362.653	90.878
362.672	90.916
362.719	90.956
362.748	90.956
362.786	90.958
362.814	90.959
362.852	90.961
362.890	90.925
362.909	90.963
362.956	90.928
362.985	90.892
363.013	90.892
363.051	90.894
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363.155	90.935
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363.222	90.938
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363.288	90.940
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363.345	90.980
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363.421	90.983
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363.525	91.025
363.553	91.063
363.582	91.028
363.620	91.066
363.658	91.068
363.686	91.070
363.724	91.108
363.752	91.108
363.790	91.072
363.828	91.113
363.866	91.114
363.895	91.116
363.923	91.115
363.952	91.117
363.989	91.082
364.027	91.082
364.065	91.047
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364.293	91.094
364.321	91.058
364.359	91.021
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364.530	91.028
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364.596	91.032

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364.662	91.034
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364.757	91.075
364.795	91.077
364.824	91.004
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364.899	91.081
364.928	91.083
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365.203	90.981
365.231	90.907
365.269	90.945
365.297	90.947
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365.364	90.912
365.402	90.914
365.430	90.916
365.459	90.916
365.497	90.918
365.534	90.918
365.563	90.921
365.601	90.923
365.629	90.887
365.667	90.925
365.706	90.852
365.734	90.816
365.773	90.816
365.801	90.818
365.830	90.855
365.868	90.821
365.906	90.822
365.935	90.824
365.973	90.788
366.011	90.826
366.040	90.866
366.078	90.866
366.107	90.830

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366.212	90.759
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366.279	90.763
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366.375	90.804
366.403	90.767
366.442	90.769
366.480	90.807
366.508	90.809
366.547	90.773
366.575	90.811
366.614	90.813
366.642	90.813
366.680	90.816
366.709	90.818
366.738	90.818
366.776	90.745
366.814	90.784
366.852	90.786
366.881	90.787
366.919	90.825
366.958	90.827
366.996	90.829
367.034	90.756
367.063	90.793
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367.130	90.758
367.168	90.798
367.196	90.800
367.235	90.763
367.273	90.727
367.302	90.729
367.330	90.730
367.378	90.732
367.407	90.770
367.426	90.770
367.464	90.772
367.502	90.737
367.531	90.775
367.560	90.738
367.598	90.740
367.626	90.742

367.665	90.780
367.703	90.782
367.732	90.784
367.770	90.748
367.798	90.824
367.837	90.825
367.865	90.789
367.913	90.791
367.942	90.791
367.980	90.793
368.009	90.795
368.037	90.833
368.076	90.835
368.114	90.798
368.152	90.837
368.171	90.837
368.219	90.878
368.257	90.880
368.286	90.880
368.314	90.882
368.353	90.882
368.381	90.922
368.420	90.961
368.458	90.925
368.486	90.887
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368.553	90.929
368.592	90.967
368.620	91.006
368.649	91.008
368.678	91.046
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368.754	91.048
368.792	91.050
368.830	91.015
368.859	91.015
368.897	91.017
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368.964	91.095
369.002	91.095
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369.098	91.138
369.127	91.138
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369.232	91.142
369.270	91.144
369.308	91.183
369.346	91.185
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369.442	91.227
369.471	91.189
369.509	91.191
369.547	91.230
369.576	91.232
369.614	91.234
369.652	91.234
369.681	91.236
369.719	91.237
369.757	91.239
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369.853	91.281
369.891	91.245
369.920	91.208
369.958	91.210
369.987	91.210
370.025	91.212
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370.092	91.290
370.120	91.217
370.159	91.217
370.197	91.257
370.226	91.257
370.264	91.297
370.302	91.298
370.340	91.338
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370.398	91.340
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370.474	91.381
370.493	91.381
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370.579	91.385
370.608	91.423
370.636	91.423
370.675	91.426
370.703	91.426

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370.770	91.431
370.808	91.393
370.837	91.395
370.875	91.395
370.914	91.398
370.942	91.400
370.971	91.362
371.009	91.440
371.047	91.442
371.076	91.480
371.105	91.480
371.133	91.445
371.172	91.484
371.210	91.484
371.238	91.487
371.286	91.525
371.315	91.527
371.344	91.527
371.382	91.529
371.420	91.531
371.449	91.495
371.487	91.496
371.516	91.534
371.544	91.498
371.583	91.501
371.621	91.539
371.668	91.541
371.697	91.541
371.735	91.543
371.764	91.546
371.793	91.507
371.831	91.510
371.860	91.548
371.898	91.512
371.927	91.476
371.965	91.478
372.003	91.516
372.032	91.592
372.070	91.556
372.098	91.520
372.127	91.558
372.165	91.561
372.194	91.525
372.232	91.527

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372.529	91.614
372.567	91.576
372.595	91.578
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372.672	91.581
372.701	91.583
372.739	91.585
372.767	91.585
372.806	91.587
372.834	91.587
372.873	91.590
372.911	91.592
372.939	91.592
372.978	91.557
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373.140	91.525
373.180	91.527
373.210	91.565
373.240	91.567
373.270	91.569
373.310	91.572
373.340	91.574
373.380	91.612
373.410	91.614
373.440	91.614
373.470	91.543
373.510	91.619
373.540	91.621
373.580	91.585
373.620	91.587
373.650	91.587
373.680	91.590
373.710	91.630
373.740	91.630

373.810	91.634
373.850	91.673
373.890	91.639
373.900	91.639
373.950	91.679
373.970	91.679
374.020	91.645
374.050	91.683
374.110	91.650
374.150	91.652
374.180	91.652
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374.250	91.619
374.280	91.583
374.320	91.584
374.350	91.548
374.420	91.591
374.500	91.594
374.530	91.557
374.550	91.559
374.590	91.561
374.630	91.525
374.670	91.528
374.710	91.530
374.740	91.568
374.760	91.533
374.800	91.533
374.830	91.535
374.870	91.575
374.900	91.538
374.930	91.578
374.970	91.580
374.990	91.545
375.020	91.469
375.060	91.471
375.090	91.511
375.130	91.550
375.160	91.514
375.190	91.592
375.230	91.592
375.270	91.558
375.300	91.559
375.330	91.561
375.370	91.563
375.400	91.563

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375.460	91.529
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375.570	91.534
375.610	91.499
375.630	91.501
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375.700	91.467
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375.780	91.507
375.800	91.472
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375.870	91.512
375.910	91.514
375.940	91.516
375.980	91.480
376.010	91.519
376.040	91.521
376.080	91.485
376.110	91.525
376.140	91.525
376.180	91.490
376.220	91.492
376.250	91.494
376.280	91.496
376.310	91.536
376.340	91.460
376.380	91.462
376.420	91.465
376.450	91.467
376.480	91.469
376.510	91.545
376.540	91.583
376.580	91.549
376.620	91.512
376.650	91.552
376.690	91.554
376.710	91.518
376.750	91.556
376.790	91.596
376.820	91.598
376.860	91.600
376.890	91.563
376.920	91.603

376.960	91.605
376.990	91.607
377.030	91.607
377.060	91.647
377.100	91.650
377.130	91.614
377.170	91.616
377.200	91.655
377.230	91.657
377.270	91.659
377.300	91.697
377.330	91.661
377.360	91.701
377.400	91.666
377.440	91.666
377.470	91.706
377.510	91.746
377.540	91.746
377.570	91.748
377.600	91.788
377.630	91.752
377.670	91.715
377.710	91.755
377.740	91.719
377.770	91.760
377.800	91.760
377.840	91.800
377.880	91.764
377.910	91.802
377.950	91.842
377.980	91.883
378.010	91.885
378.050	91.885
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378.150	91.854
378.180	91.892
378.210	91.894
378.250	91.896
378.280	91.897
378.310	91.899
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378.420	91.905
378.450	91.905
378.480	91.946

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378.560	91.910
378.590	91.912
378.620	91.915
378.650	91.917
378.690	91.917
378.720	91.957
378.760	91.921
378.790	91.886
378.830	91.962
378.890	92.004
378.930	91.968
378.960	91.968
378.990	91.971
379.030	91.973
379.060	91.975
379.090	91.976
379.130	92.016
379.160	92.018
379.200	92.056
379.240	92.096
379.270	92.022
379.300	91.987
379.330	91.989
379.380	92.029
379.420	92.067
379.450	92.032
379.480	92.034
379.510	92.034
379.620	92.041
379.640	92.041
379.710	92.045
379.740	92.085
379.770	92.047
379.810	92.087
379.840	92.127
379.870	92.128
379.910	92.130
379.940	92.132
379.970	92.132
380.010	92.097
380.040	92.137
380.080	92.177
380.110	92.215
380.140	92.218

380.170	92.220
380.210	92.220
380.240	92.222
380.280	92.224
380.310	92.226
380.350	92.227
380.380	92.229
380.410	92.269
380.450	92.271
380.480	92.235
380.520	92.311
380.550	92.276
380.580	92.278
380.610	92.316
380.650	92.318
380.680	92.320
380.720	92.284
380.750	92.285
380.780	92.325
380.820	92.327
380.850	92.329
380.890	92.256
380.920	92.332
380.950	92.372
380.990	92.336
381.020	92.298
381.060	92.376
381.090	92.379
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381.160	92.343
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381.420	92.358
381.460	92.396
381.490	92.398
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381.630	92.329
381.650	92.369
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381.800	92.414
381.830	92.378
381.860	92.381

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381.920	92.345
381.970	92.347
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382.090	92.392
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382.170	92.396
382.200	92.396
382.240	92.360
382.270	92.400
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382.610	92.380
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382.700	92.459
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382.800	92.465
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382.910	92.470
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383.110	92.479
383.140	92.519
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383.240	92.488
383.360	92.531
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383.480	92.538
383.560	92.540
383.580	92.542
383.610	92.545
383.650	92.509
383.690	92.547
383.760	92.551
383.820	92.554
383.890	92.558
383.960	92.523
384.020	92.527
384.050	92.529
384.120	92.494

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384.190	92.498
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384.400	92.507
384.440	92.547
384.470	92.588
384.530	92.590
384.630	92.595
384.670	92.597
384.710	92.599
384.770	92.526
384.800	92.528
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384.880	92.532
384.910	92.610
384.980	92.537
385.050	92.579
385.070	92.617
385.110	92.657
385.180	92.660
385.220	92.587
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385.420	92.674
385.460	92.714
385.490	92.714
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385.580	92.682
385.620	92.645
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385.690	92.687
385.730	92.690
385.760	92.652
385.800	92.692
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385.850	92.694
385.900	92.699
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385.960	92.739
386.000	92.741
386.030	92.779
386.070	92.705
386.110	92.745

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386.160	92.712
386.200	92.712
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386.270	92.678
386.310	92.680
386.340	92.721
386.370	92.721
386.400	92.685
386.440	92.649
386.480	92.689
386.510	92.691
386.550	92.693
386.580	92.694
386.620	92.696
386.640	92.698
386.670	92.736
386.710	92.738
386.750	92.702
386.790	92.667
386.820	92.669
386.850	92.707
386.890	92.747
386.910	92.787
386.950	92.789
386.990	92.792
387.020	92.754
387.050	92.832
387.090	92.796
387.120	92.797
387.160	92.760
387.190	92.801
387.220	92.765
387.260	92.805
387.300	92.845
387.330	92.883
387.360	92.847
387.400	92.887
387.420	92.887
387.460	92.889
387.500	92.930
387.540	92.932
387.560	92.894
387.600	92.972
387.640	92.937

387.660	92.939
387.700	92.941
387.730	92.979
387.770	92.981
387.810	93.021
387.830	93.059
387.880	93.062
387.900	93.064
387.940	93.028
387.970	92.992
388.010	93.032
388.040	93.032
388.080	93.073
388.110	93.075
388.150	93.001
388.190	93.041
388.210	93.041
388.250	93.043
388.280	93.046
388.310	93.084
388.350	93.086
388.390	93.164
388.420	93.204
388.460	93.168
388.520	93.171
388.590	93.251
388.630	93.289
388.670	93.291
388.700	93.331
388.730	93.370
388.760	93.334
388.800	93.336
388.840	93.376
388.880	93.378
388.910	93.418
388.940	93.495
388.980	93.573
389.000	93.537
389.040	93.613
389.080	93.615
389.110	93.655
389.150	93.696
389.190	93.698
389.220	93.736
389.260	93.776

389.280	93.814
389.320	93.816
389.360	93.819
389.390	93.859
389.430	93.899
389.460	93.937
389.500	93.977
389.530	93.980
389.560	93.980
389.600	94.058
389.630	94.136
389.670	94.139
389.710	94.139
389.740	94.141
389.780	94.181
389.810	94.183
389.840	94.260
389.880	94.262
389.910	94.378
389.950	94.380
389.980	94.380
390.020	94.383
390.050	94.347
390.080	94.385
390.120	94.388
390.160	94.390
390.190	94.430
390.230	94.432
390.260	94.508
390.290	94.549
390.320	94.513
390.370	94.515
390.400	94.591
390.430	94.518
390.470	94.520
390.510	94.598
390.530	94.598
390.570	94.601
390.600	94.603
390.640	94.643
390.680	94.605
390.710	94.646
390.750	94.648
390.770	94.650
390.800	94.650

390.840	94.690
390.870	94.692
390.910	94.693
390.940	94.695
391.010	94.775
391.050	94.664
391.080	94.740
391.110	94.742
391.150	94.745
391.190	94.823
391.230	94.861
391.250	94.901
391.280	94.865
391.320	94.830
391.360	94.906
391.400	94.908
391.430	94.948
391.470	94.912
391.500	94.953
391.530	94.991
391.560	94.955
391.630	94.995
391.670	94.960
391.700	95.000
391.730	95.040
391.760	95.040
391.800	95.004
391.830	95.083
391.870	95.047
391.900	95.011
391.940	95.011
391.970	95.090
392.000	95.054
392.070	95.058
392.110	95.020
392.180	95.063
392.200	95.065
392.300	95.069
392.340	95.033
392.370	95.072
392.410	95.112
392.470	95.154
392.580	95.121
392.610	95.085
392.650	95.125

392.700	95.052
392.740	95.016
392.780	95.056
392.820	95.058
392.860	95.022
392.890	95.024
392.910	95.024
392.980	95.067
393.090	95.033
393.130	94.998
393.150	94.962
393.220	94.964
393.250	94.966
393.300	94.969
393.330	94.933
393.360	94.897
393.420	94.937
393.460	94.901
393.500	94.904
393.560	94.868
393.600	94.908
393.670	94.874
393.690	94.838
393.810	94.805
393.830	94.807
393.870	94.809
393.970	94.738
394.000	94.740
394.040	94.780
394.070	94.744
394.100	94.744
394.140	94.747
394.170	94.711
394.210	94.713
394.230	94.751
394.310	94.717
394.330	94.681
394.370	94.684
394.410	94.648
394.520	94.615
394.550	94.655
394.580	94.619
394.650	94.583
394.710	94.587
394.780	94.590

394.840	94.518
394.870	94.556
394.980	94.448
395.020	94.451
395.040	94.453
395.080	94.379
395.120	94.379
395.150	94.343
395.230	94.386
395.250	94.388
395.280	94.350
395.320	94.352
395.360	94.354
395.430	94.358
395.450	94.359
395.490	94.285
395.510	94.249
395.560	94.289
395.590	94.289
395.620	94.253
395.660	94.294
395.700	94.296
395.730	94.298
395.750	94.298
395.790	94.262
395.820	94.302
395.890	94.267
395.930	94.307
395.960	94.233
395.990	94.273
396.020	94.313
396.090	94.239
396.130	94.242
396.160	94.206
396.200	94.208
396.220	94.208
396.250	94.248
396.290	94.289
396.320	94.327
396.360	94.253
396.400	94.217
396.430	94.257
396.470	94.297
396.500	94.224
396.530	94.224

396.570	94.226
396.600	94.190
396.630	94.192
396.660	94.154
396.700	94.194
396.740	94.197
396.770	94.199
396.810	94.201
396.840	94.201
396.870	94.165
396.900	94.167
396.930	94.131
396.980	94.134
397.040	94.174
397.080	94.176
397.110	94.178
397.140	94.143
397.170	94.143
397.210	94.183
397.240	94.185
397.280	94.149
397.310	94.151
397.350	94.152
397.380	94.116
397.420	94.118
397.450	94.082
397.490	94.084
397.510	94.122
397.540	94.124
397.580	94.126
397.620	94.091
397.660	94.055
397.690	94.017
397.730	94.019
397.760	94.021
397.790	94.024
397.820	94.062
397.850	94.064
397.930	94.068
397.960	94.108
397.990	94.108
398.020	94.073
398.060	94.075
398.100	94.115
398.140	94.079

398.170	94.043
398.200	94.121
398.230	94.084
398.260	94.086
398.300	94.088
398.340	94.052
398.370	94.092
398.410	94.095
398.440	94.135
398.470	94.061
398.510	94.101
398.530	94.142
398.570	94.144
398.610	94.146
398.640	94.148
398.680	94.150
398.710	94.229
398.740	94.191
398.780	94.231
398.840	94.235
398.910	94.278
398.980	94.282
399.020	94.284
399.050	94.287
399.090	94.251
399.120	94.253
399.180	94.257
399.220	94.260
399.260	94.262
399.290	94.264
399.360	94.268
399.390	94.307
399.430	94.273
399.470	94.275
399.500	94.275
399.520	94.277
399.560	94.280
399.630	94.284
399.660	94.286
399.690	94.326
399.740	94.329
399.770	94.331
399.800	94.409
399.840	94.373
399.900	94.378

399.940	94.380
399.970	94.382
400.000	94.420
400.050	94.425
400.070	94.387
400.110	94.427
400.150	94.431
400.180	94.431
400.210	94.472
400.270	94.438
400.340	94.442
400.450	94.487
400.480	94.489
400.510	94.453
400.540	94.455
400.580	94.496
400.650	94.500
400.680	94.500
400.720	94.541
400.760	94.507
400.780	94.507
400.820	94.471
400.850	94.473
400.880	94.514
400.920	94.516
400.950	94.518
400.990	94.520
401.010	94.560
401.060	94.563
401.080	94.563
401.120	94.567
401.160	94.569
401.190	94.608
401.220	94.610
401.250	94.574
401.290	94.614
401.320	94.654
401.360	94.657
401.390	94.621
401.430	94.623
401.460	94.587
401.500	94.627
401.520	94.630
401.550	94.670
401.590	94.672

401.620	94.636
401.660	94.715
401.690	94.639
401.730	94.681
401.770	94.683
401.800	94.683
401.840	94.649
401.860	94.649
401.900	94.652
401.930	94.616
401.960	94.618
402.000	94.582
402.060	94.548
402.130	94.667
402.190	94.631
402.230	94.598
402.300	94.524
402.410	94.607
402.480	94.611
402.500	94.613
402.540	94.577
402.570	94.580
402.640	94.508
402.680	94.510
402.700	94.510
402.740	94.552
402.810	94.517
402.850	94.483
402.870	94.445
402.910	94.485
402.970	94.528
403.040	94.494
403.080	94.534
403.150	94.539
403.180	94.503
403.210	94.505
403.250	94.507
403.280	94.471
403.310	94.510
403.340	94.435
403.380	94.476
403.420	94.516
403.450	94.518
403.490	94.520
403.520	94.485

403.550	94.487
403.580	94.451
403.610	94.453
403.650	94.455
403.690	94.457
403.720	94.498
403.790	94.502
403.860	94.506
403.880	94.468
403.910	94.471
403.950	94.473
403.990	94.513
404.020	94.477
404.060	94.480
404.090	94.482
404.130	94.446
404.200	94.450
404.230	94.452
404.290	94.457
404.330	94.459
404.400	94.387
404.460	94.389
404.530	94.470
404.560	94.472
404.630	94.438
404.730	94.483
404.800	94.488
404.840	94.490
404.870	94.492
404.890	94.456
404.930	94.496
404.970	94.537
405.040	94.541
405.100	94.543
405.140	94.545
405.200	94.550
405.270	94.554
405.300	94.556
405.340	94.520
405.370	94.599
405.410	94.563
405.450	94.604
405.480	94.644
405.520	94.646
405.540	94.610

405.570	94.650
405.600	94.652
405.670	94.655
405.710	94.619
405.750	94.583
405.810	94.663
405.850	94.704
405.880	94.630
405.910	94.632
405.950	94.634
405.980	94.598
406.020	94.639
406.120	94.607
406.150	94.609
406.180	94.647
406.210	94.651
406.240	94.652
406.280	94.654
406.320	94.696
406.380	94.737
406.480	94.781
406.530	94.784
406.550	94.748
406.590	94.788
406.650	94.792
406.680	94.794
406.730	94.759
406.760	94.761
406.830	94.765
406.860	94.767
406.890	94.808
406.920	94.770
406.960	94.812
406.990	94.812
407.030	94.776
407.060	94.817
407.130	94.859
407.170	94.823
407.200	94.864
407.230	94.828
407.260	94.868
407.330	94.949
407.370	94.951
407.400	94.915
407.470	94.919

407.510	94.921
407.540	94.885
407.600	94.928
407.640	94.892
407.670	94.932
407.710	94.934
407.740	94.935
407.780	94.977
407.810	95.015
407.850	94.981
407.880	94.943
407.900	94.984
407.930	94.986
407.970	94.950
408.010	94.952
408.040	94.954
408.080	94.995
408.110	95.035
408.140	94.999
408.180	95.001
408.210	95.042
408.240	95.044
408.270	95.084
408.310	95.086
408.350	94.974
408.380	95.014
408.420	95.016
408.450	95.016
408.480	95.019
408.510	95.059
408.550	95.063
408.580	95.025
408.620	95.066
408.650	95.068
408.680	95.032
408.720	95.034
408.750	94.998
408.780	95.000
408.820	95.002
408.850	95.043
408.890	95.083
408.910	95.085
408.950	95.087
408.990	95.090
409.020	95.168

409.050	95.130
409.080	95.132
409.130	95.099
409.160	95.137
409.190	95.101
409.230	95.141
409.260	95.143
409.300	95.145
409.320	95.147
409.360	95.226
409.390	95.190
409.430	95.230
409.460	95.194
409.500	95.235
409.530	95.237
409.570	95.239
409.600	95.280
409.630	95.320
409.670	95.322
409.700	95.324
409.740	95.288
409.770	95.367
409.800	95.331
409.840	95.333
409.870	95.412
409.900	95.414
409.940	95.416
410.010	95.420
410.040	95.384
410.070	95.386
410.140	95.429
410.170	95.431
410.200	95.510
410.240	95.512
410.310	95.476
410.350	95.478
410.380	95.519
410.420	95.599
410.460	95.601
410.480	95.603
410.510	95.604
410.550	95.646
410.580	95.646
410.610	95.610
410.650	95.612

410.680	95.576
410.720	95.655
410.760	95.619
410.790	95.621
410.820	95.623
410.850	95.663
410.920	95.744
410.950	95.746
410.990	95.710
411.020	95.712
411.060	95.753
411.090	95.678
411.120	95.719
411.160	95.721
411.190	95.762
411.230	95.802
411.250	95.766
411.280	95.768
411.320	95.770
411.360	95.734
411.390	95.775
411.460	95.777
411.490	95.779
411.530	95.821
411.570	95.862
411.600	95.864
411.630	95.828
411.660	95.868
411.690	95.830
411.720	95.833
411.760	95.911
411.790	95.837
411.830	95.877
411.870	95.880
411.940	95.846
411.970	95.886
412.010	95.850
412.030	95.814
412.060	95.855
412.100	95.857
412.170	95.900
412.200	95.823
412.230	95.825
412.270	95.828
412.310	95.792

412.340	95.870
412.380	95.873
412.400	95.913
412.430	95.877
412.470	95.841
412.510	95.881
412.540	95.884
412.570	95.886
412.600	95.888
412.640	95.890
412.680	95.930
412.710	95.894
412.740	95.856
412.780	95.897
412.810	95.940
412.840	95.941
412.870	95.904
412.910	95.906
412.940	95.870
412.980	95.872
413.010	95.836
413.050	95.876
413.080	95.879
413.110	95.881
413.160	95.921
413.180	95.923
413.210	95.925
413.250	95.890
413.290	95.968
413.320	96.009
413.350	95.972
413.380	95.934
413.420	95.939
413.450	95.900
413.490	95.981
413.520	95.981
413.560	95.986
413.580	96.024
413.620	96.028
413.650	96.028
413.690	96.032
413.720	95.995
413.750	96.035
413.790	96.037
413.820	96.001

413.860	96.003
413.890	96.044
413.950	96.010
413.990	96.050
414.020	96.014
414.060	96.016
414.090	95.980
414.120	96.021
414.200	96.025
414.230	95.989
414.260	96.027
414.300	96.031
414.330	96.032
414.360	96.074
414.390	96.036
414.430	96.078
414.460	96.080
414.490	96.119
414.530	96.123
414.560	96.123
414.600	96.087
414.630	96.089
414.670	96.091
414.700	96.055
414.730	96.096
414.770	96.098
414.800	96.100
414.830	96.179
414.870	96.181
414.900	96.183
414.940	96.186
414.970	96.149
415.010	96.151
415.040	96.153
415.070	96.156
415.110	96.120
415.140	96.198
415.170	96.162
415.210	96.203
415.240	96.205
415.270	96.207
415.310	96.247
415.350	96.249
415.380	96.251
415.410	96.292

415.450	96.294
415.490	96.374
415.520	96.337
415.560	96.339
415.590	96.379
415.610	96.305
415.640	96.345
415.680	96.309
415.720	96.387
415.750	96.313
415.780	96.315
415.810	96.317
415.850	96.281
415.880	96.243
415.920	96.286
415.960	96.326
415.990	96.290
416.030	96.293
416.060	96.371
416.080	96.333
416.120	96.337
416.150	96.337
416.190	96.380
416.220	96.382
416.250	96.344
416.290	96.424
416.330	96.388
416.360	96.388
416.390	96.391
416.430	96.433
416.470	96.395
416.500	96.397
416.530	96.361
416.560	96.402
416.590	96.365
416.660	96.370
416.690	96.410
416.730	96.412
416.760	96.452
416.800	96.531
416.830	96.495
416.870	96.536
416.900	96.576
416.940	96.540
416.970	96.504

417.000	96.544
417.020	96.547
417.060	96.549
417.100	96.513
417.130	96.553
417.170	96.555
417.200	96.481
417.240	96.483
417.270	96.485
417.310	96.487
417.340	96.526
417.380	96.492
417.410	96.454
417.440	96.494
417.470	96.496
417.500	96.499
417.530	96.463
417.560	96.503
417.600	96.429
417.640	96.469
417.670	96.471
417.710	96.473
417.740	96.437
417.770	96.478
417.810	96.442
417.840	96.442
417.880	96.406
417.900	96.408
417.930	96.372
417.970	96.413
418.000	96.415
418.040	96.455
418.070	96.381
418.120	96.383
418.150	96.347
418.190	96.349
418.220	96.351
418.250	96.353
418.290	96.316
418.330	96.318
418.350	96.282
418.380	96.284
418.410	96.325
418.450	96.327
418.470	96.327

418.510	96.331
418.530	96.293
418.580	96.297
418.600	96.297
418.650	96.300
418.670	96.340
418.710	96.343
418.740	96.383
418.780	96.385
418.810	96.311
418.840	96.275
418.870	96.275
418.910	96.318
418.940	96.280
419.010	96.323
419.080	96.289
419.120	96.253
419.150	96.255
419.180	96.255
419.210	96.296
419.250	96.260
419.280	96.302
419.310	96.341
419.350	96.345
419.380	96.345
419.410	96.386
419.440	96.350
419.480	96.352
419.510	96.392
419.540	96.356
419.580	96.396
419.620	96.322
419.650	96.324
419.720	96.367
419.750	96.331
419.790	96.333
419.820	96.335
419.860	96.337
419.890	96.300
419.930	96.342
419.960	96.344
420.030	96.310
420.060	96.310
420.090	96.274
420.150	96.278

420.190	96.280
420.280	96.364
420.350	96.329
420.380	96.370
420.440	96.372
420.480	96.374
420.590	96.382
420.620	96.423
420.650	96.387
420.710	96.429
420.740	96.429
420.780	96.393
420.810	96.434
420.850	96.359
420.880	96.400
420.910	96.402
420.950	96.404
421.020	96.409
421.060	96.411
421.090	96.413
421.120	96.377
421.150	96.379
421.190	96.419
421.230	96.460
421.270	96.385
421.300	96.387
421.370	96.468
421.400	96.394
421.440	96.396
421.510	96.477
421.540	96.441
421.570	96.405
421.590	96.443
421.620	96.486
421.660	96.448
421.690	96.488
421.720	96.490
421.760	96.492
421.790	96.533
421.830	96.536
421.860	96.538
421.900	96.502
421.930	96.542
421.960	96.506
422.000	96.546

422.030	96.549
422.060	96.550
422.090	96.476
422.120	96.555
422.160	96.595
422.190	96.598
422.220	96.560
422.260	96.562
422.300	96.566
422.330	96.568
422.360	96.570
422.400	96.610
422.430	96.651
422.470	96.653
422.490	96.693
422.520	96.658
422.590	96.700
422.620	96.662
422.690	96.666
422.730	96.670
422.770	96.632
422.790	96.711
422.860	96.753
422.930	96.759
422.960	96.761
422.990	96.763
423.030	96.765
423.060	96.805
423.120	96.809
423.160	96.812
423.200	96.813
423.230	96.816
423.270	96.857
423.300	96.859
423.330	96.822
423.370	96.825
423.400	96.866
423.420	96.828
423.450	96.829
423.490	96.794
423.590	96.800
423.630	96.764
423.660	96.804
423.730	96.808
423.790	96.773

423.830	96.777
423.860	96.777
423.880	96.741
423.960	96.784
423.990	96.748
424.050	96.752
424.090	96.754
424.150	96.757
424.190	96.721
424.230	96.685
424.290	96.688
424.320	96.691
424.350	96.693
424.390	96.733
424.490	96.740
424.520	96.704
424.560	96.666
424.630	96.670
424.690	96.675
424.730	96.638
424.790	96.643
424.820	96.607
424.850	96.686
424.890	96.649
424.920	96.690
424.950	96.651
424.980	96.615
425.070	96.620
425.100	96.622
425.130	96.625
425.170	96.627
425.200	96.591
425.230	96.593
425.260	96.595
425.300	96.557
425.330	96.638
425.360	96.562
425.400	96.563
425.460	96.567
425.500	96.570
425.540	96.573
425.570	96.575
425.600	96.615
425.640	96.540
425.670	96.543

425.700	96.543
425.740	96.547
425.790	96.589
425.850	96.554
425.880	96.477
425.920	96.558
425.960	96.522
425.980	96.560
426.020	96.603
426.090	96.567
426.160	96.533
426.180	96.535
426.210	96.499
426.250	96.501
426.290	96.426
426.350	96.507
426.420	96.589
426.450	96.551
426.490	96.514
426.560	96.559
426.590	96.561
426.620	96.561
426.680	96.527
426.750	96.610
426.820	96.574
426.880	96.578
426.910	96.580
426.960	96.582
427.020	96.625
427.060	96.628
427.080	96.668
427.120	96.670
427.150	96.672
427.180	96.712
427.280	96.758
427.310	96.759
427.390	96.766
427.450	96.767
427.480	96.731
427.520	96.810
427.580	96.777
427.610	96.778
427.640	96.780
427.670	96.782
427.710	96.785

427.750	96.826
427.810	96.868
427.850	96.870
427.880	96.872
427.910	96.875
427.950	96.877
428.010	96.919
428.080	96.885
428.150	96.889
428.190	96.930
428.230	97.011
428.260	96.973
428.290	97.014
428.310	97.016
428.340	97.018
428.380	97.019
428.410	97.021
428.480	96.988
428.550	97.069
428.580	97.071
428.610	97.073
428.680	97.116
428.720	97.118
428.760	97.120
428.820	97.203
428.860	97.127
428.930	97.131
428.960	97.172
429.000	97.174
429.020	97.215
429.050	97.178
429.090	97.180
429.150	97.223
429.220	97.189
429.250	97.191
429.320	97.272
429.350	97.274
429.420	97.279
429.450	97.242
429.490	97.244
429.520	97.285
429.560	97.326
429.620	97.368
429.700	97.335
429.730	97.337

429.750	97.339
429.780	97.300
429.810	97.341
429.850	97.305
429.890	97.309
429.950	97.351
430.010	97.315
430.090	97.321
430.160	97.286
430.190	97.326
430.250	97.331
430.290	97.294
430.350	97.258
430.390	97.222
430.460	97.264
430.480	97.228
430.510	97.230
430.540	97.232
430.610	97.275
430.680	97.279
430.710	97.243
430.750	97.245
430.780	97.246
430.820	97.209
430.920	97.255
430.950	97.218
430.980	97.220
431.010	97.222
431.080	97.148
431.110	97.189
431.180	97.193
431.200	97.195
431.240	97.159
431.270	97.161
431.340	97.125
431.380	97.129
431.410	97.129
431.510	97.136
431.540	97.176
431.570	97.140
431.600	97.142
431.670	97.108
431.740	97.112
431.770	97.074
431.810	97.078

431.840	97.040
431.910	97.122
431.940	97.085
431.960	97.126
432.030	97.092
432.070	97.133
432.110	97.096
432.140	97.137
432.200	97.140
432.230	97.143
432.300	97.069
432.370	97.073
432.410	97.037
432.440	97.038
432.480	97.041
432.540	97.044
432.570	97.125
432.610	97.087
432.650	97.089
432.660	97.091
432.730	97.057
432.770	97.138
432.800	97.139
432.840	97.179
432.870	97.143
432.910	97.145
432.930	97.147
433.000	97.112
433.040	97.230
433.070	97.155
433.100	97.158
433.210	97.124
433.240	97.205
433.300	97.209
433.340	97.171
433.380	97.136
433.400	97.098
433.470	97.142
433.500	97.144
433.530	97.146
433.560	97.146
433.600	97.150
433.640	97.191
433.670	97.153
433.690	97.155

433.730	97.157
433.770	97.198
433.830	97.202
433.870	97.205
433.890	97.207
433.940	97.209
434.000	97.213
434.040	97.216
434.070	97.218
434.100	97.218
434.120	97.259
434.160	97.262
434.190	97.224
434.220	97.267
434.260	97.269
434.300	97.231
434.360	97.273
434.390	97.276
434.460	97.280
434.490	97.244
434.530	97.245
434.560	97.210
434.590	97.210
434.620	97.251
434.690	97.256
434.730	97.258
434.760	97.261
434.830	97.303
434.850	97.305
434.890	97.307
434.920	97.386
434.950	97.311
434.980	97.391
435.020	97.355
435.050	97.316
435.080	97.358
435.110	97.321
435.150	97.363
435.180	97.363
435.220	97.367
435.250	97.367
435.290	97.372
435.320	97.334
435.350	97.413
435.380	97.338

435.420	97.378
435.450	97.381
435.490	97.422
435.520	97.463
435.550	97.426
435.610	97.430
435.670	97.393
435.710	97.437
435.740	97.477
435.800	97.481
435.840	97.484
435.940	97.527
435.970	97.490
436.010	97.532
436.070	97.537
436.140	97.501
436.170	97.542
436.210	97.545
436.240	97.547
436.280	97.509
436.330	97.591
436.400	97.558
436.440	97.482
436.460	97.522
436.500	97.445
436.530	97.447
436.570	97.449
436.630	97.493
436.670	97.495
436.700	97.458
436.740	97.500
436.810	97.544
436.840	97.467
436.870	97.507
436.930	97.471
437.000	97.555
437.030	97.557
437.060	97.597
437.100	97.561
437.160	97.526
437.190	97.567
437.220	97.529
437.260	97.531
437.290	97.572
437.330	97.536

437.370	97.538
437.400	97.541
437.460	97.466
437.500	97.508
437.530	97.548
437.560	97.550
437.600	97.552
437.630	97.594
437.660	97.556
437.690	97.557
437.730	97.562
437.750	97.562
437.790	97.604
437.820	97.606
437.880	97.532
437.930	97.573
437.950	97.496
437.990	97.538
438.020	97.539
438.060	97.542
438.090	97.505
438.120	97.546
438.150	97.510
438.190	97.551
438.220	97.551
438.260	97.594
438.290	97.556
438.320	97.598
438.350	97.600
438.390	97.562
438.450	97.568
438.480	97.568
438.510	97.532
438.590	97.576
438.650	97.619
438.730	97.623
438.760	97.586
438.800	97.548
438.830	97.591
438.850	97.591
438.890	97.593
438.920	97.595
438.980	97.560
439.020	97.603
439.050	97.604

439.090	97.567
439.150	97.571
439.180	97.573
439.250	97.539
439.280	97.579
439.350	97.584
439.370	97.584
439.450	97.590
439.480	97.553
439.550	97.596
439.580	97.637
439.610	97.639
439.680	97.642
439.710	97.567
439.740	97.647
439.780	97.689
439.820	97.612
439.850	97.654
439.870	97.654
439.900	97.657
439.970	97.700
440.010	97.702
440.030	97.704
440.070	97.705
440.100	97.670
440.140	97.710
440.170	97.712
440.200	97.754
440.240	97.756
440.270	97.797
440.310	97.761
440.340	97.801
440.380	97.726
440.400	97.765
440.440	97.767
440.470	97.810
440.500	97.772
440.540	97.814
440.570	97.737
440.600	97.778
440.630	97.779
440.660	97.743
440.700	97.784
440.730	97.748
440.770	97.750

440.800	97.752
440.830	97.714
440.870	97.757
440.900	97.759
440.930	97.759
440.990	97.724
441.030	97.726
441.060	97.728
441.130	97.810
441.160	97.774
441.200	97.814
441.230	97.778
441.260	97.740
441.290	97.743
441.330	97.745
441.350	97.747
441.390	97.749
441.420	97.711
441.450	97.792
441.480	97.716
441.520	97.758
441.560	97.760
441.590	97.762
441.650	97.726
441.690	97.728
441.720	97.770
441.750	97.733
441.790	97.735
441.820	97.697
441.850	97.738
441.890	97.702
441.920	97.664
441.950	97.706
441.990	97.707
442.020	97.710
442.050	97.672
442.080	97.715
442.110	97.715
442.150	97.679
442.180	97.681
442.210	97.722
442.240	97.724
442.280	97.688
442.310	97.688
442.340	97.690

442.380	97.771
442.410	97.733
442.440	97.735
442.480	97.661
442.510	97.740
442.540	97.780
442.570	97.782
442.600	97.784
442.640	97.787
442.680	97.790
442.710	97.791
442.780	97.756
442.800	97.679
442.830	97.681
442.860	97.724
442.890	97.725
442.930	97.688
442.960	97.728
443.000	97.692
443.030	97.732
443.060	97.696
443.090	97.699
443.130	97.739

CALCULATED VALUES OF Cp FOR BI-AL2O3.71 FOR 50 TO 170 °C

Temperature/K	Heat Capacity/J/mol K
320	83.9
325	84.6
330	85.2
335	85.9
340	86.5
345	87.1
350	87.8
355	88.4
360	89.1
365	89.7
370	90.3
375	91.0
380	91.6
385	92.3
390	92.9
395	93.5
400	94.2
405	94.8
410	95.4
415	96.1
420	96.7
425	97.4
430	98.0
435	98.6
440	99.3

STATISTICS FOR FIT OF DATA FROM BI-AL2O3.71 FOR 50 TO 170 °C

```
Ignoring standard deviation
   A = 43.074012      Uncertainty:   .783884
   B =    .127736     Uncertainty:   .002048
   Chi-squared:        .532E+05
```

APPENDIX E

```
      PROGRAM CPINT
$DEBUG
$NOTRUNCATE
      IMPLICIT DOUBLE PRECISION (A-H,O-Z)
      DIMENSION T(500),CP(500),FCP(500),DH(500),DS(500)
      CHARACTER*10 FILENAME,MATERIAL
    5 WRITE(*,10)
   10 FORMAT(' INPUT NAME OF FILE ',/)
      READ(*,15) FILENAME
   15 FORMAT(A10)
      IF (FILENAME.EQ.'END'.OR.FILENAME.EQ.'end') STOP
      WRITE(*,16)
   16 FORMAT(' INPUT NAME OF MATERIAL AND TRANSITION NO - ONE ITEM PER
 L
     1INE',/)
      READ(*,17) MATERIAL,NT
   17 FORMAT(A10,/,I1)
      OPEN(2,FILE=FILENAME,STATUS='UNKNOWN')
      OPEN(3,FILE='THERMO',STATUS='UNKNOWN')
      DO 150 I = 1 , 1000
      READ(2,100,END=200) T(I),CP(I)
  100 FORMAT(3X,F7.3,12X,F7.3)
      FCP(I) = CP(I)/T(I)
C     PRINT *,' T =',T(I),' CP =',CP(I),' CP/T =',FCP(I)
  150 CONTINUE
  200 ICP = I - 1
C     PRINT *,' ICP =',ICP
      CALL DQTFG(T,CP,DH,ICP)
      CALL DQTFG(T,FCP,DS,ICP)
      IF (DS(ICP).LT.1.) THEN
      PRINT *,' ENTHALPY FOR ',MATERIAL,'IS',SNGL(DH(ICP)),' J/g AT TRAN
     1SITION',NT
      PRINT *,' ENTROPY FOR ',MATERIAL,'IS',SNGL(DS(ICP)),' J/g K ',
     1'AT TRANSITION',NT
      WRITE(3,18) MATERIAL,DH(ICP),NT
   18 FORMAT(' ENTHALPY FOR ',A,'IS ',F4.1,' J/g AT TRANSITION',I2,/)
      WRITE(3,20) MATERIAL,DS(ICP),NT
   20 FORMAT(' ENTROPY FOR ',A,'IS ',F4.3,' J/g K AT TRANSITION',I2,/)
      ELSE
      PRINT *,' ENTHALPY FOR ',MATERIAL,'IS',SNGL(DH(ICP)),' J/mol AT TR
     1ANSITION',NT
      PRINT *,' ENTROPY FOR ',MATERIAL,'IS',SNGL(DS(ICP)),' J/mol K AT T
     1RANSITION',NT
      WRITE(3,23) MATERIAL,DH(ICP)/1000.D0,NT
   23 FORMAT(' ENTHALPY FOR ',A,'IS ',F5.2,' kJ/mol AT TRANSITION',I2,/)
```

```
      WRITE(3,25) MATERIAL,DS(ICP),NT
   25 FORMAT(' ENTROPY FOR ',A,'IS ',F4.1,' J/mol K AT TRANSITION',I2,/)
      ENDIF
      GO TO 5
      END
      SUBROUTINE DQTFG(X,Y,Z,NDIM)
      IMPLICIT DOUBLE PRECISION (A-H,O-Z)
      DIMENSION X(NDIM),Y(NDIM),Z(NDIM)
      SUM2 = 0.D0
      IF (NDIM - 1) 4,3,1
    1 DO 2 I = 2 , NDIM
      SUM1 = SUM2
      SUM2 = SUM2 + 0.5D0*(X(I) - X(I - 1))*(Y(I) + Y(I - 1))
C      PRINT *,' S(I-1) =',SUM1,' S(I) =',SUM2-SUM1,' I =',I
    2 Z(I - 1) = SUM1
    3 Z(NDIM) = SUM2
    4 RETURN
      END
```

APPENDIX F

FIGURES

Figure 1

Heat Capacity of Aluminum Oxide

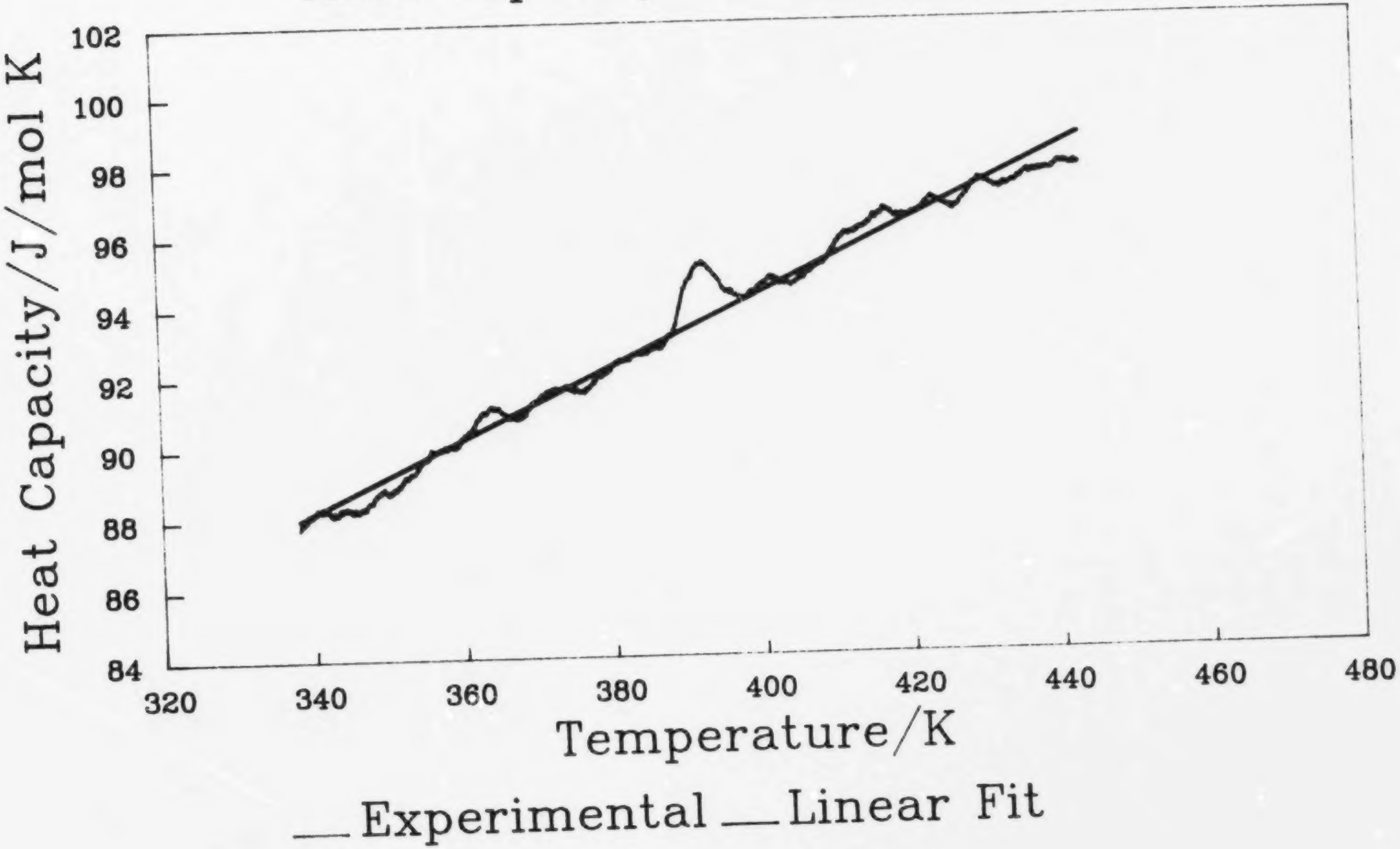


Figure 2

Heat Capacity of Aluminum Oxide

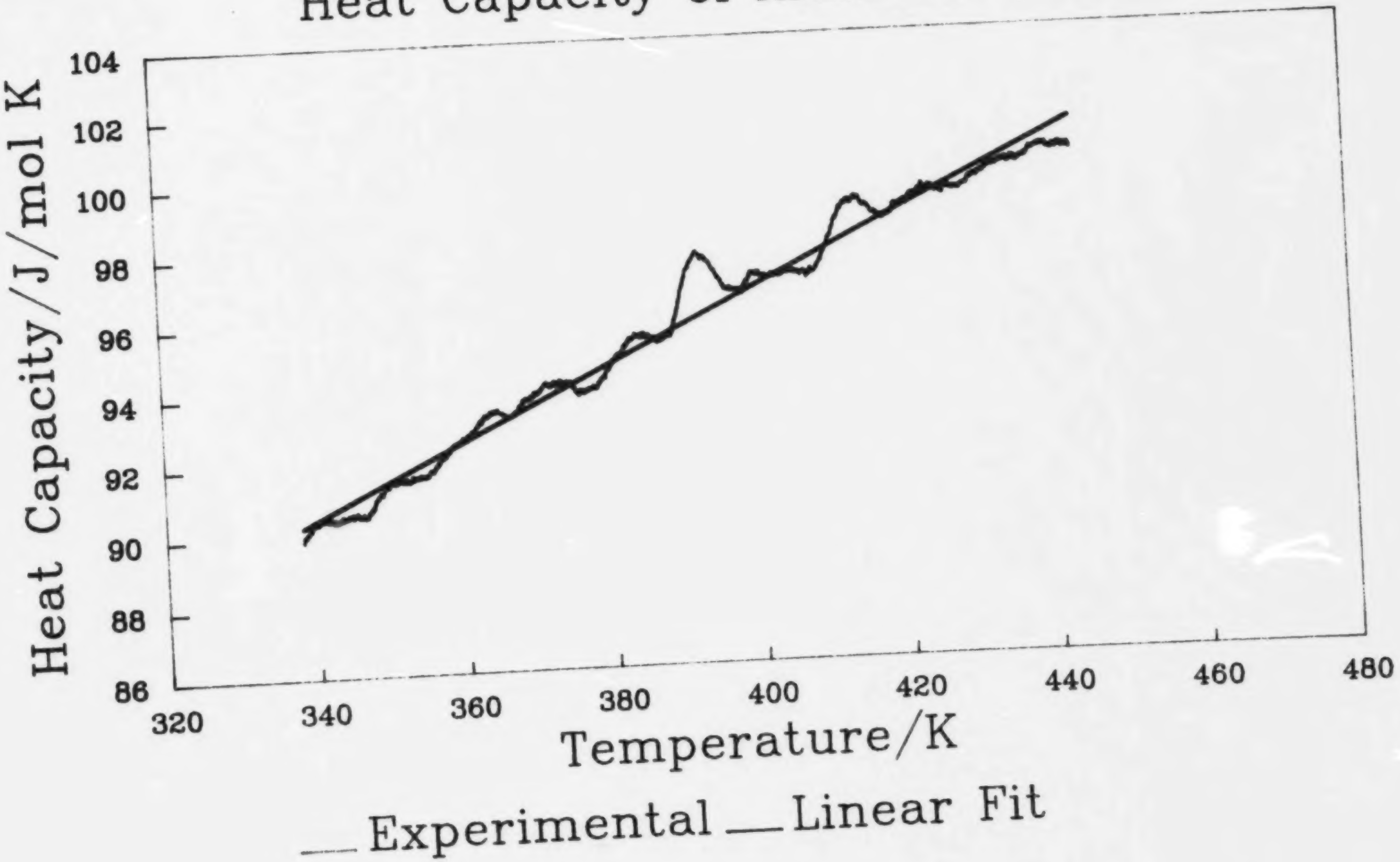


Figure 3

Heat Capacity of Aluminum Oxide

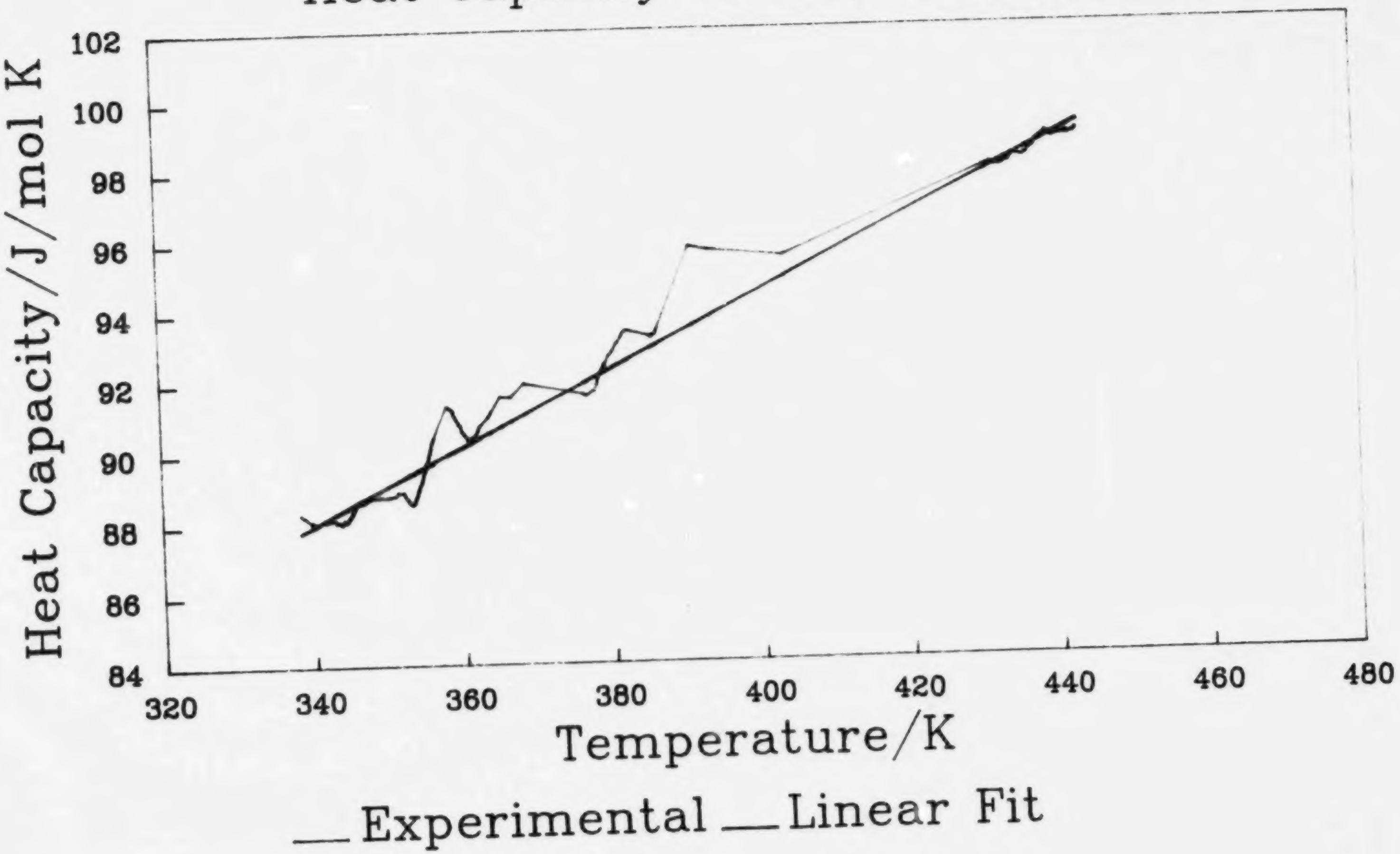


Figure 4

Heat Capacity of Aluminum Oxide

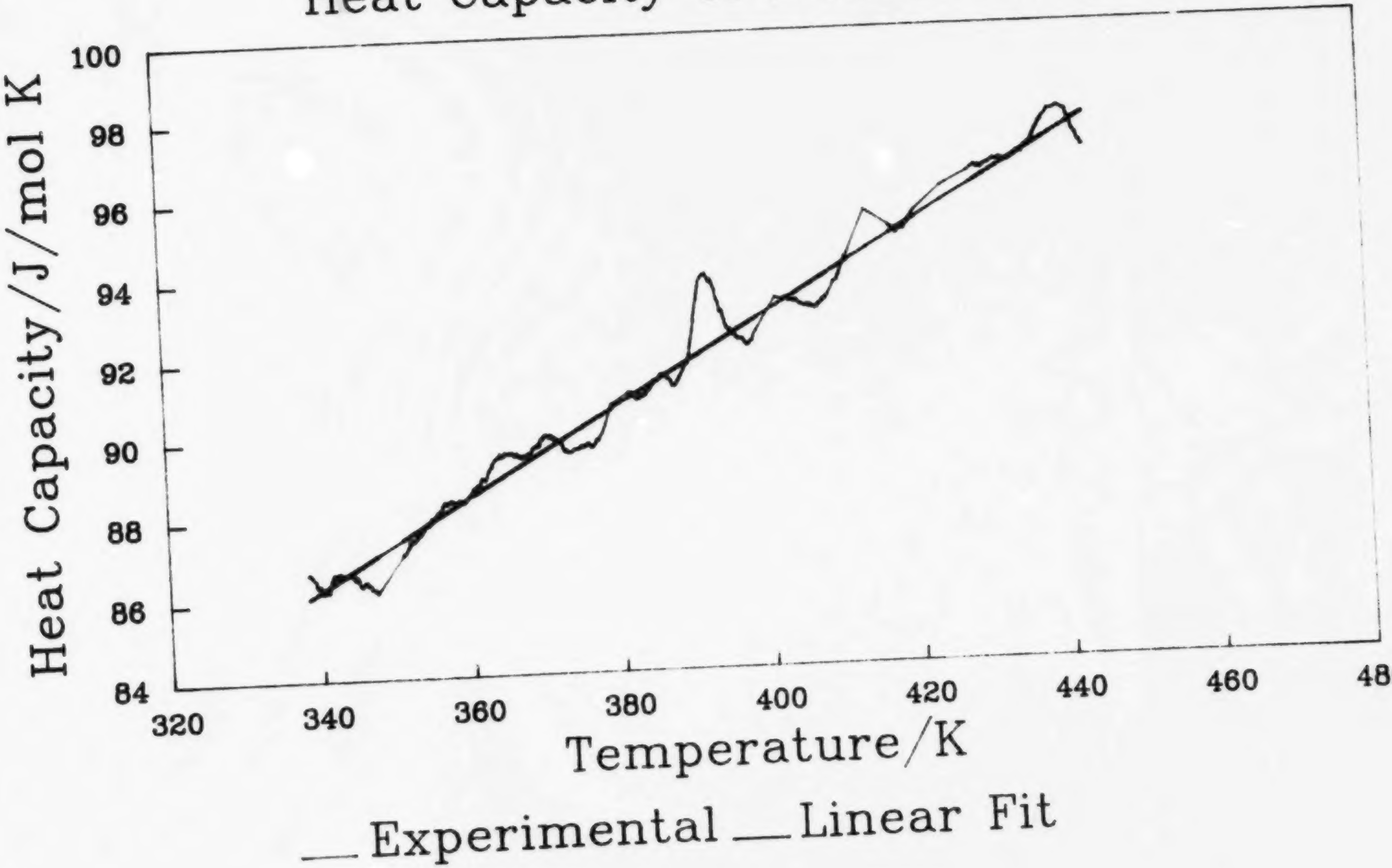


Figure 5

Heat Capacity of Aluminum Oxide

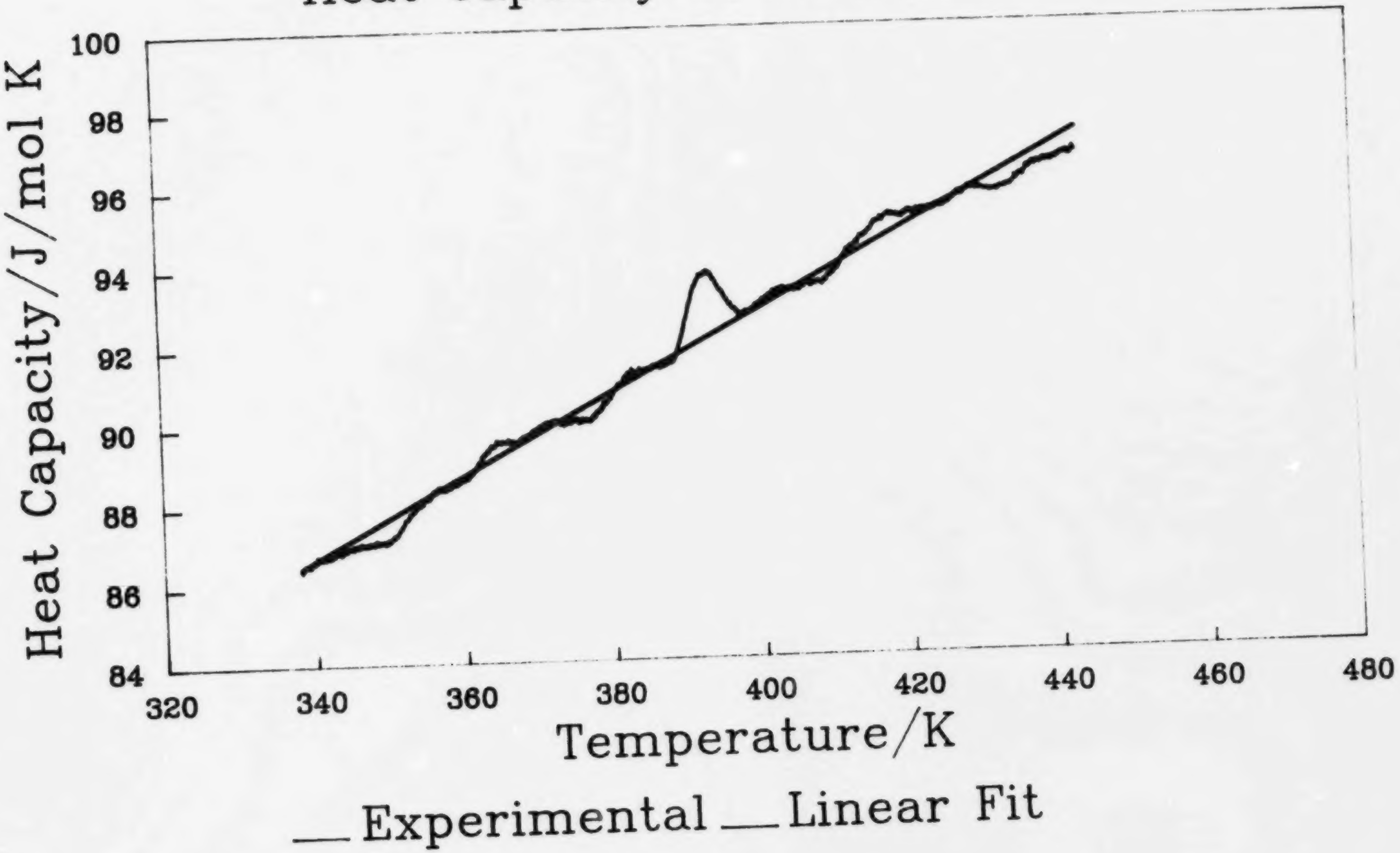


Figure 6

Heat Capacity of Aluminum Oxide

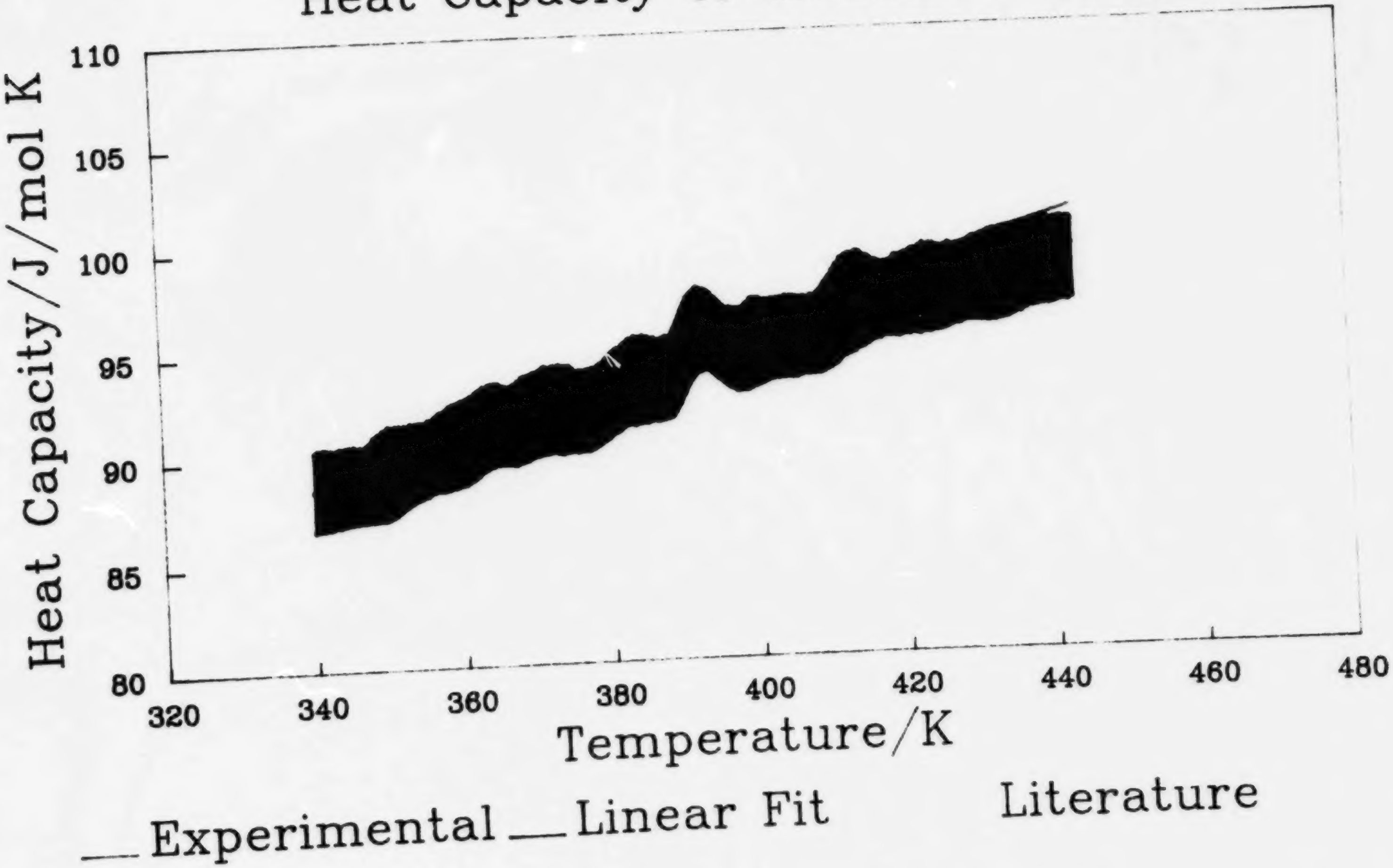


Figure 7

Heat Capacity of Aluminum Oxide from Literature

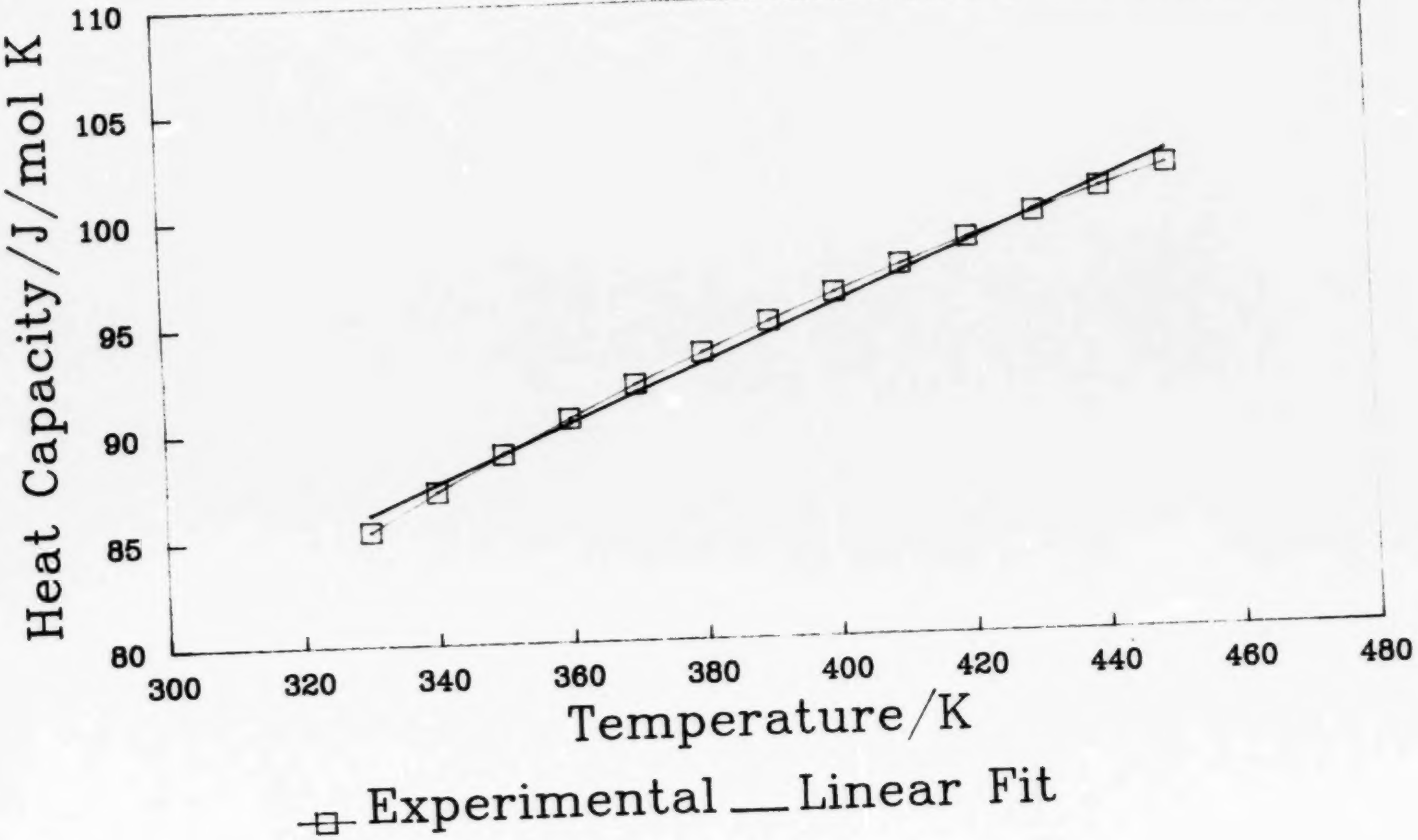


Figure 8

Heat capacity of Benzoic Acid

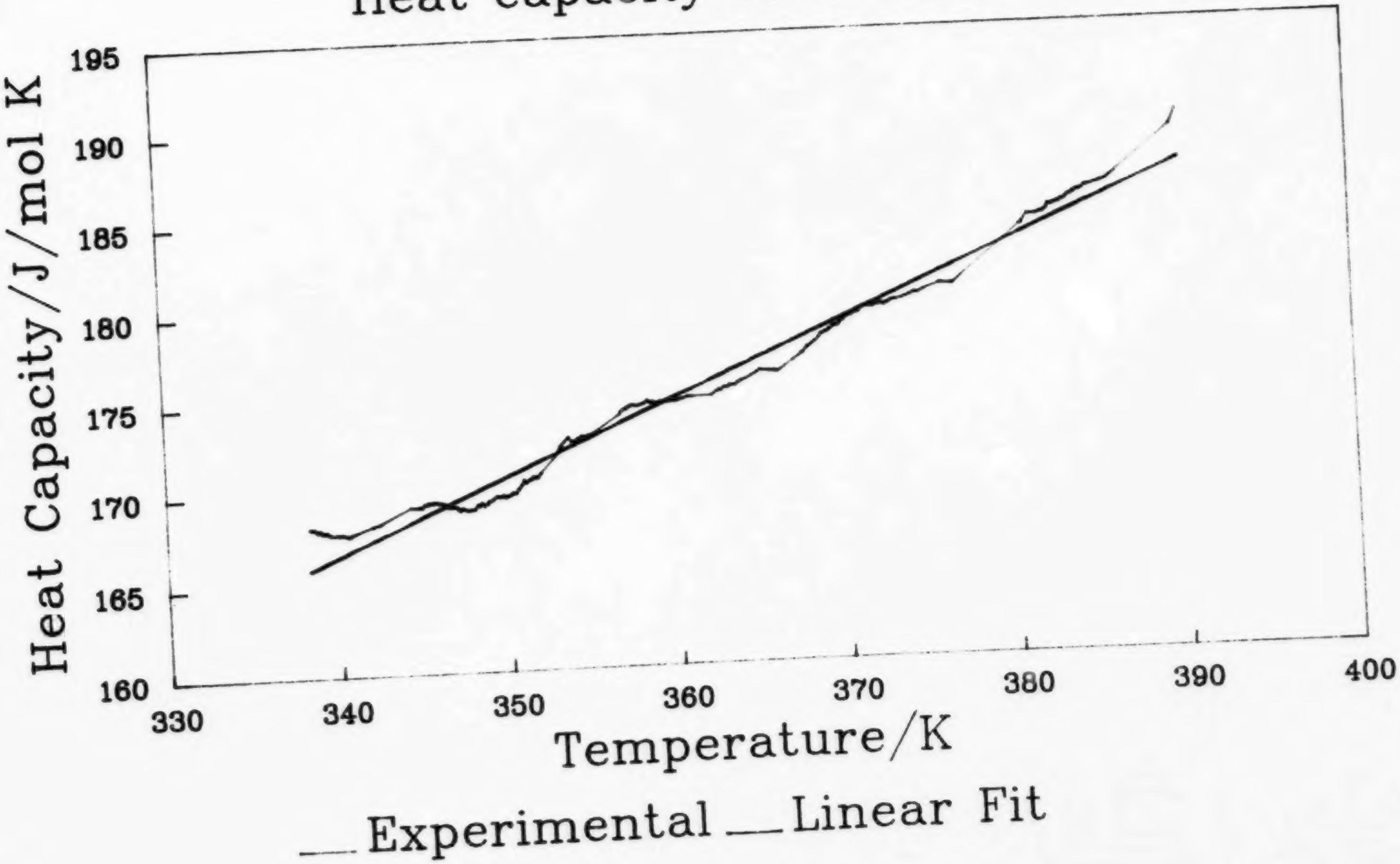


Figure 9

Heat Capacity of Benzoic Acid

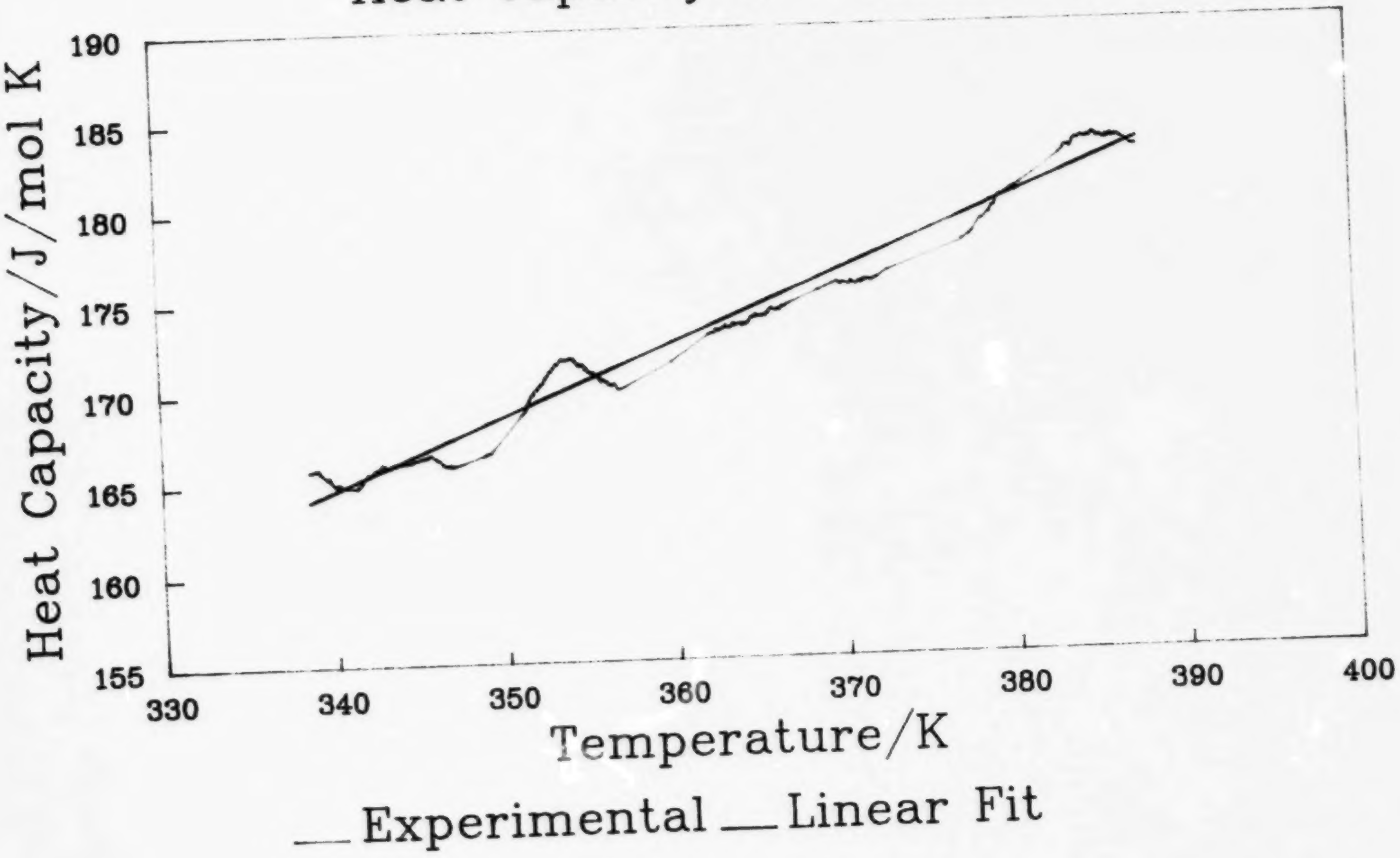


Figure 10

Heat capacity of Benzoic Acid

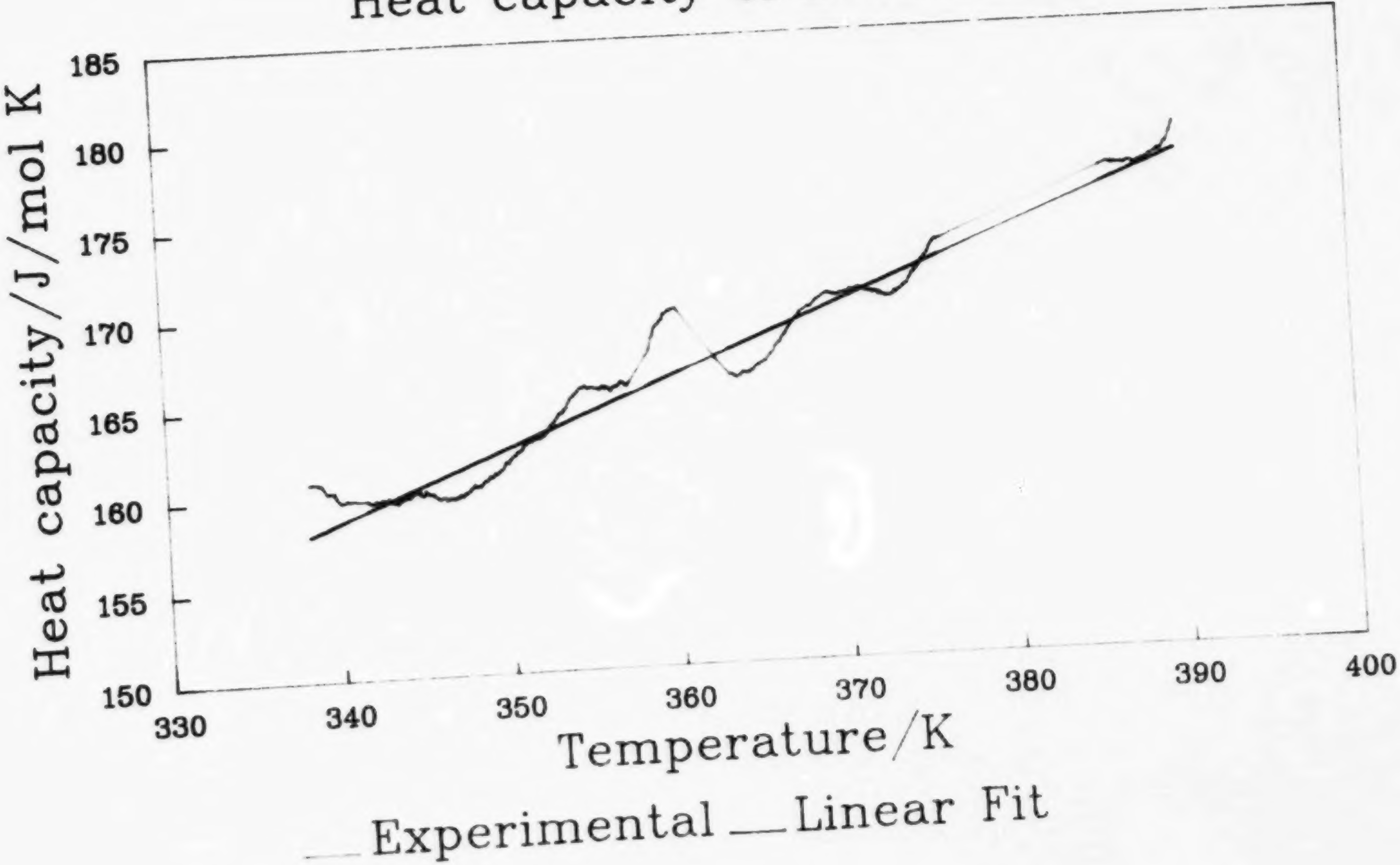
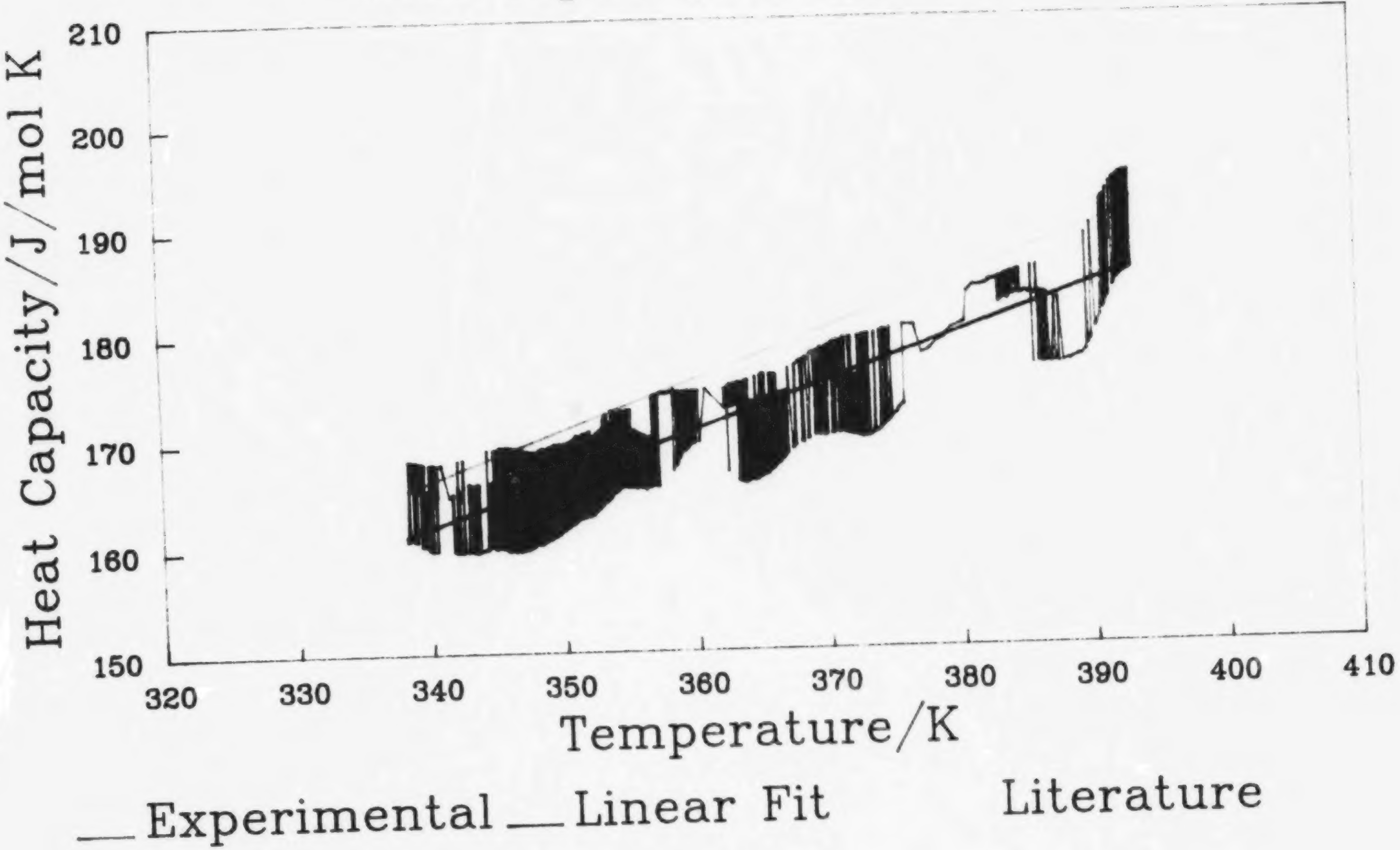


Figure 11

Heat Capacity of Benzoic Acid



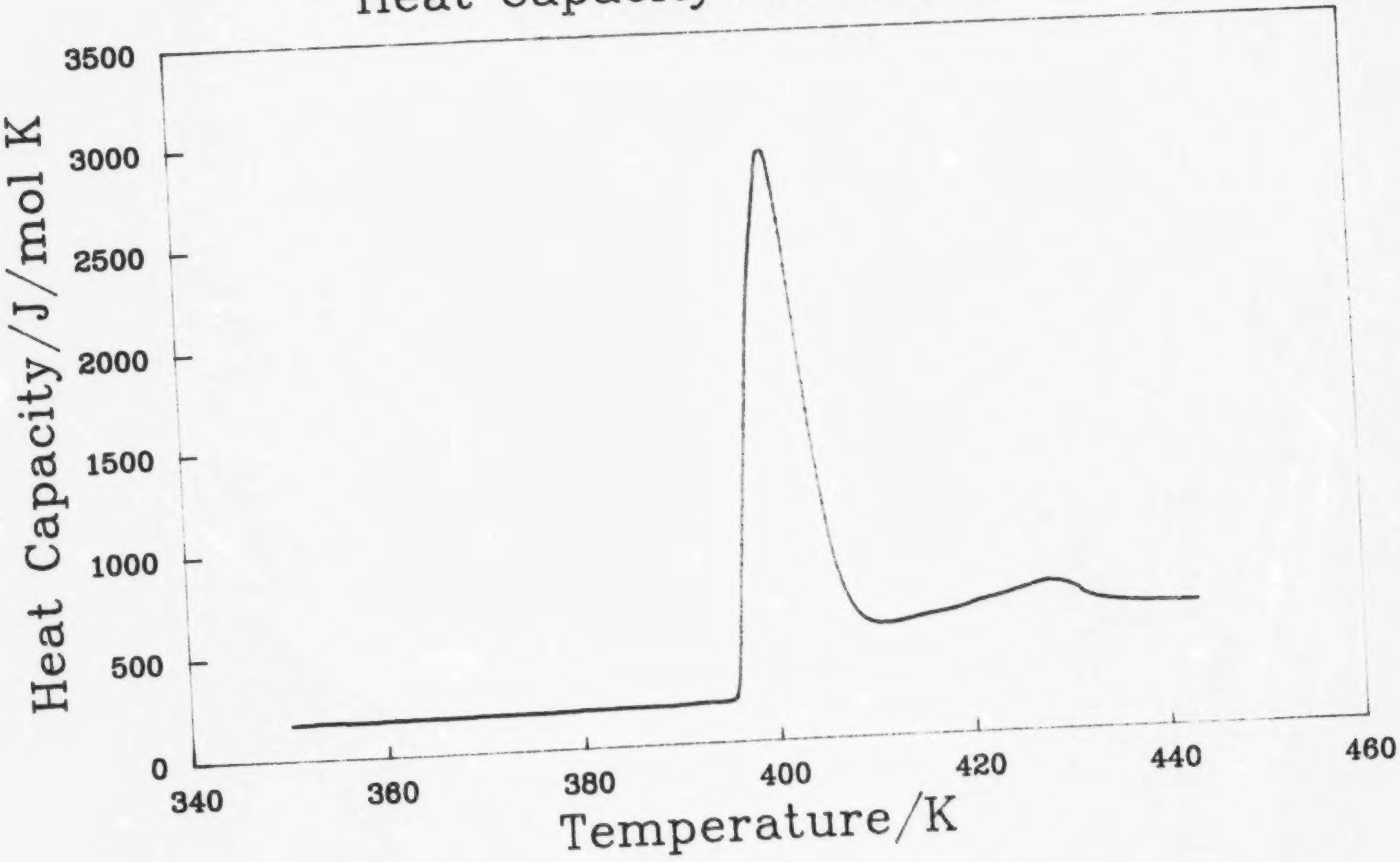


Figure 12

Heat Capacity of Benzoic Acid

Figure 13

Heat Capacity of Ammonium Nitrate

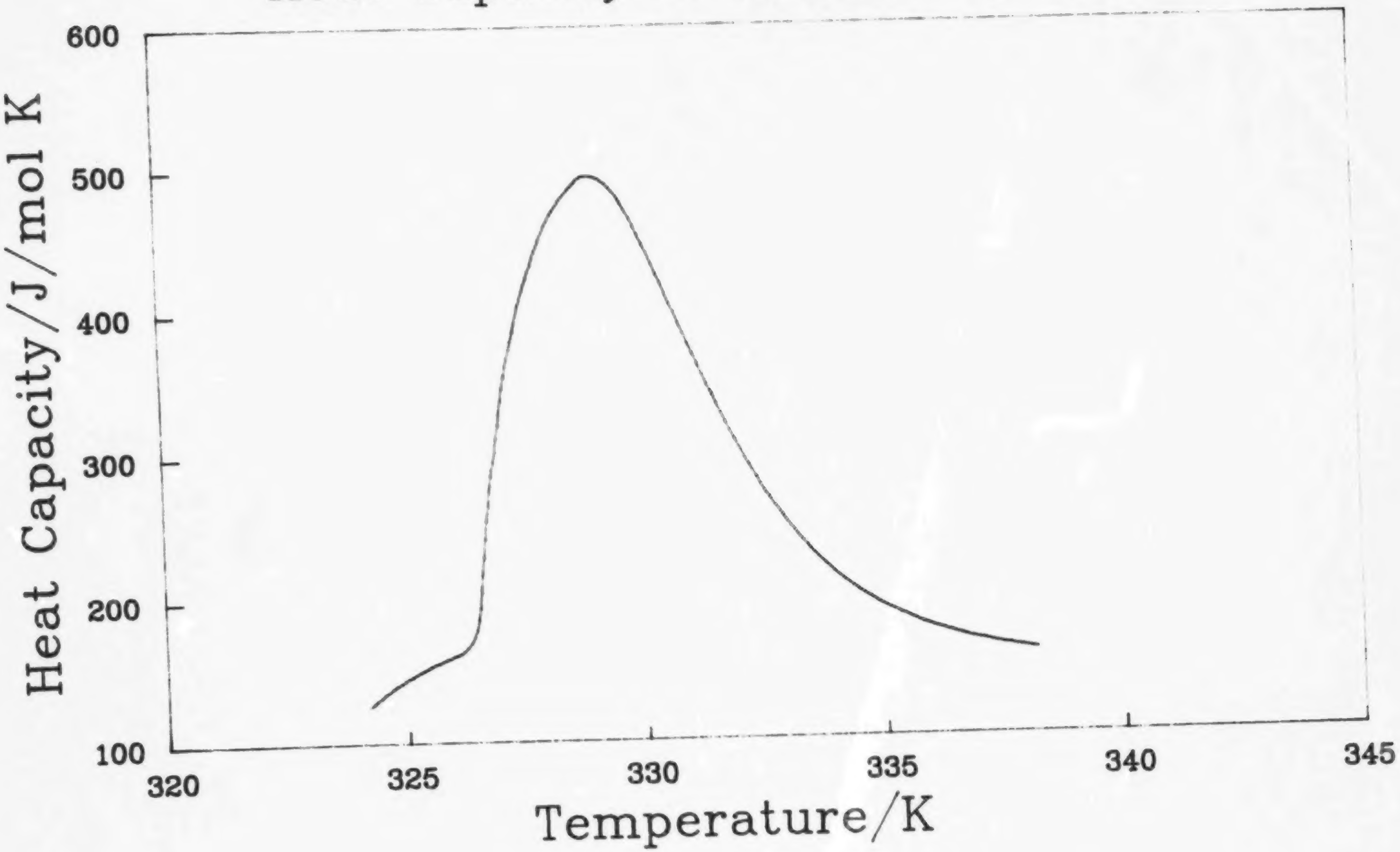


Figure 14

Heat Capacity of Ammonium Nitrate

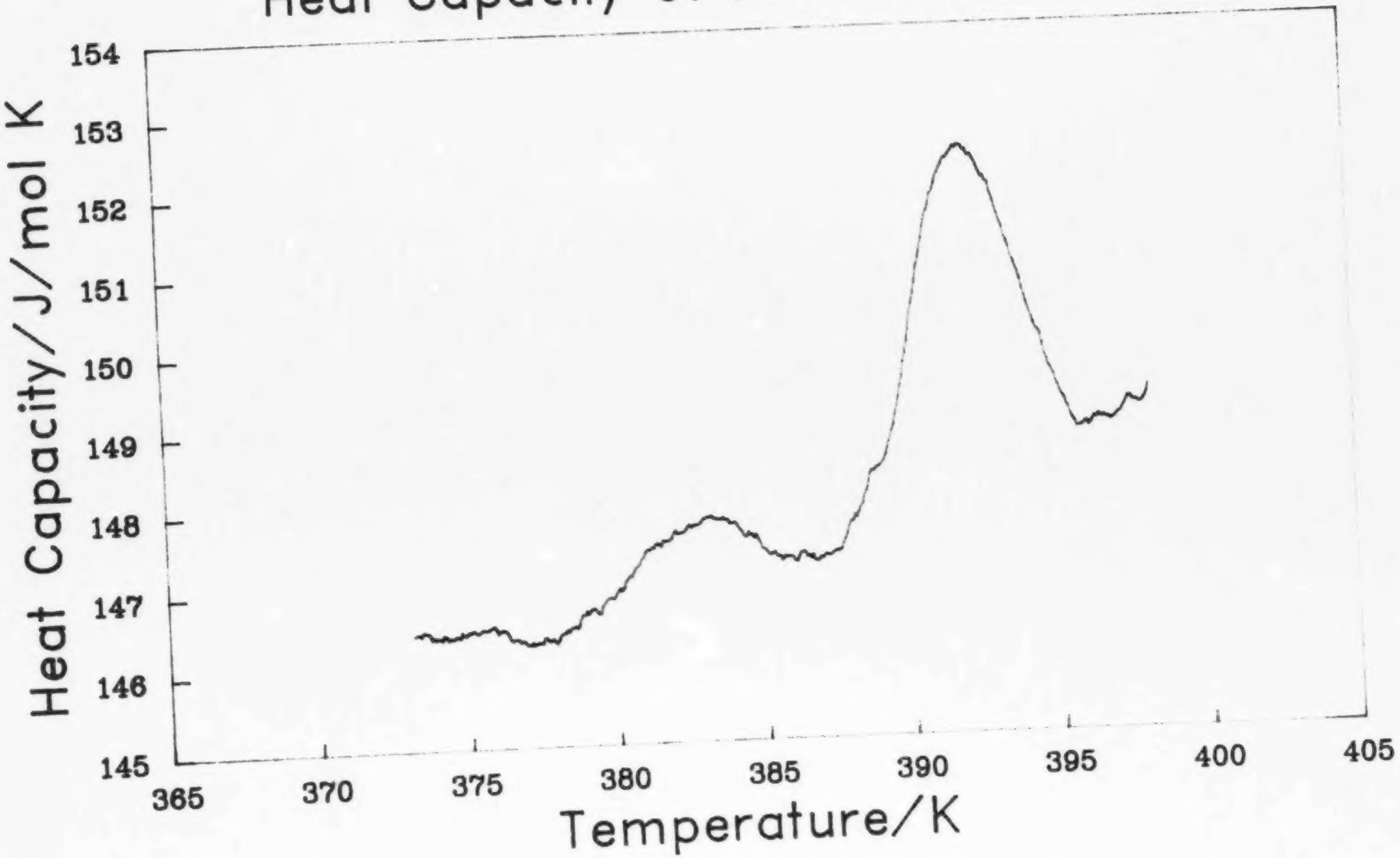


Figure 15

Heat Capacity of Ammonium Nitrate

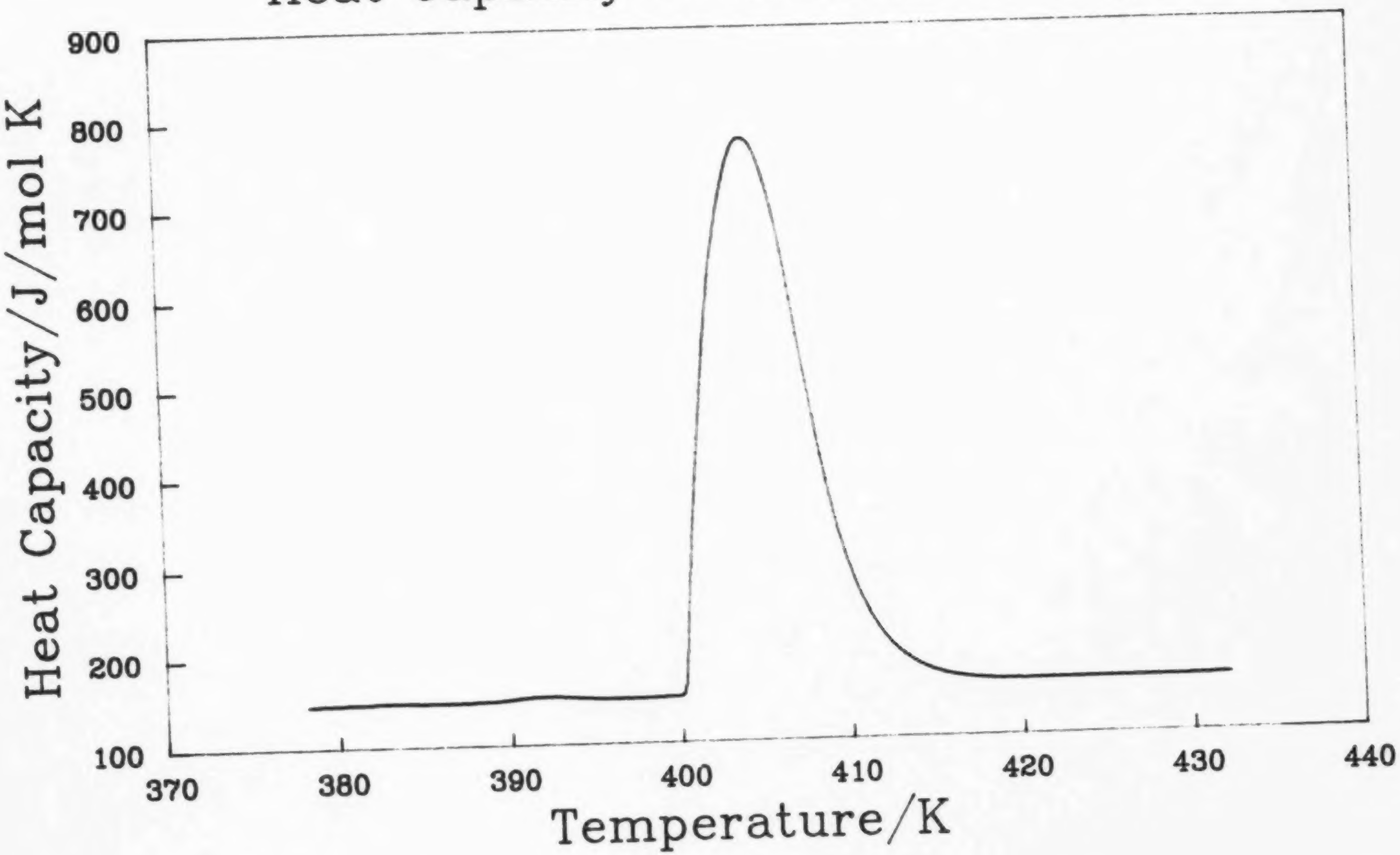


Figure 16

Heat Capacity of Ammonium Nitrate

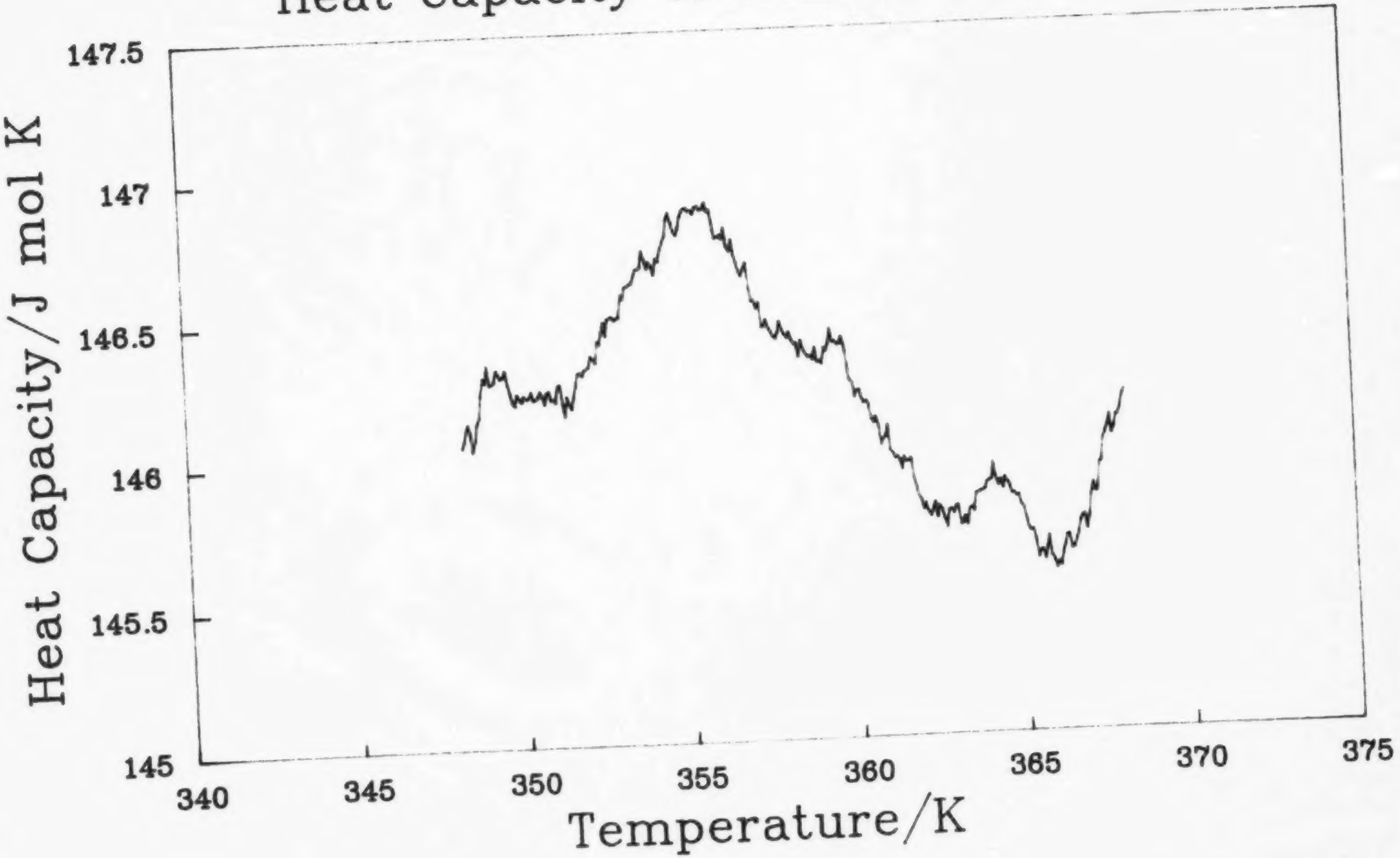


Figure 17

Heat Capacity of KNO3 doped AN

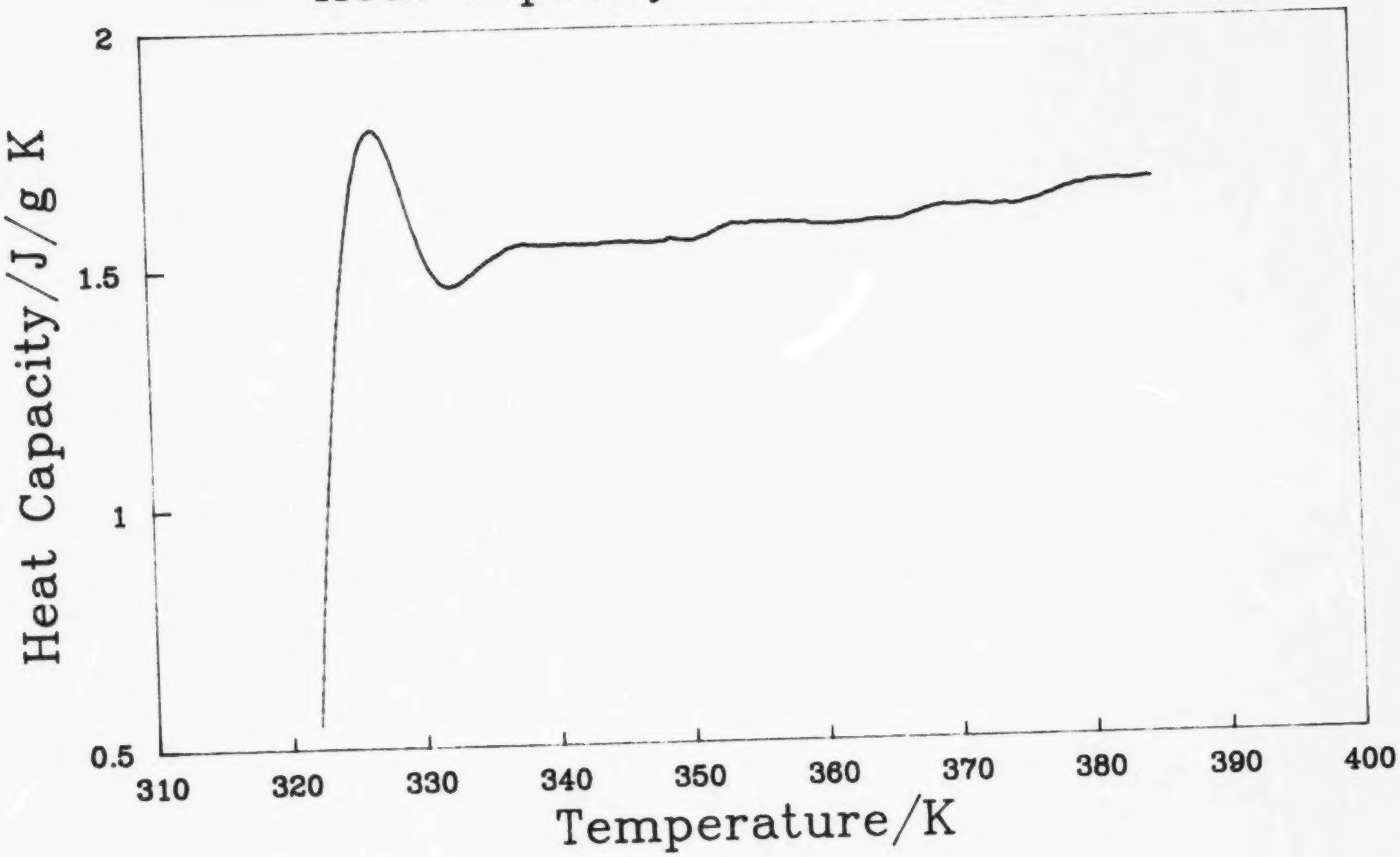


Figure 18

Heat Capacity of KNO3 doped AN

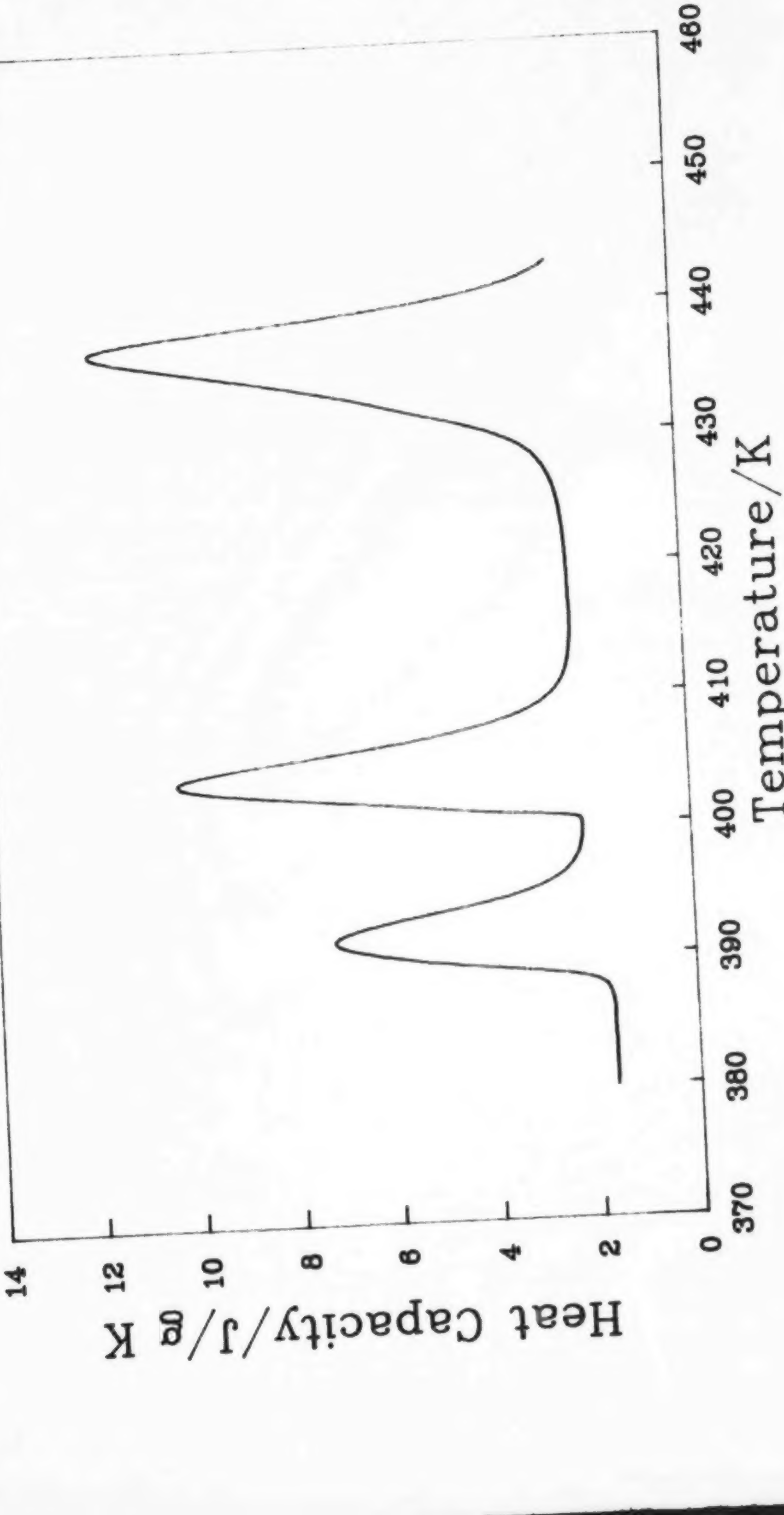


Figure 19

Heat Capacity of CuO doped AN

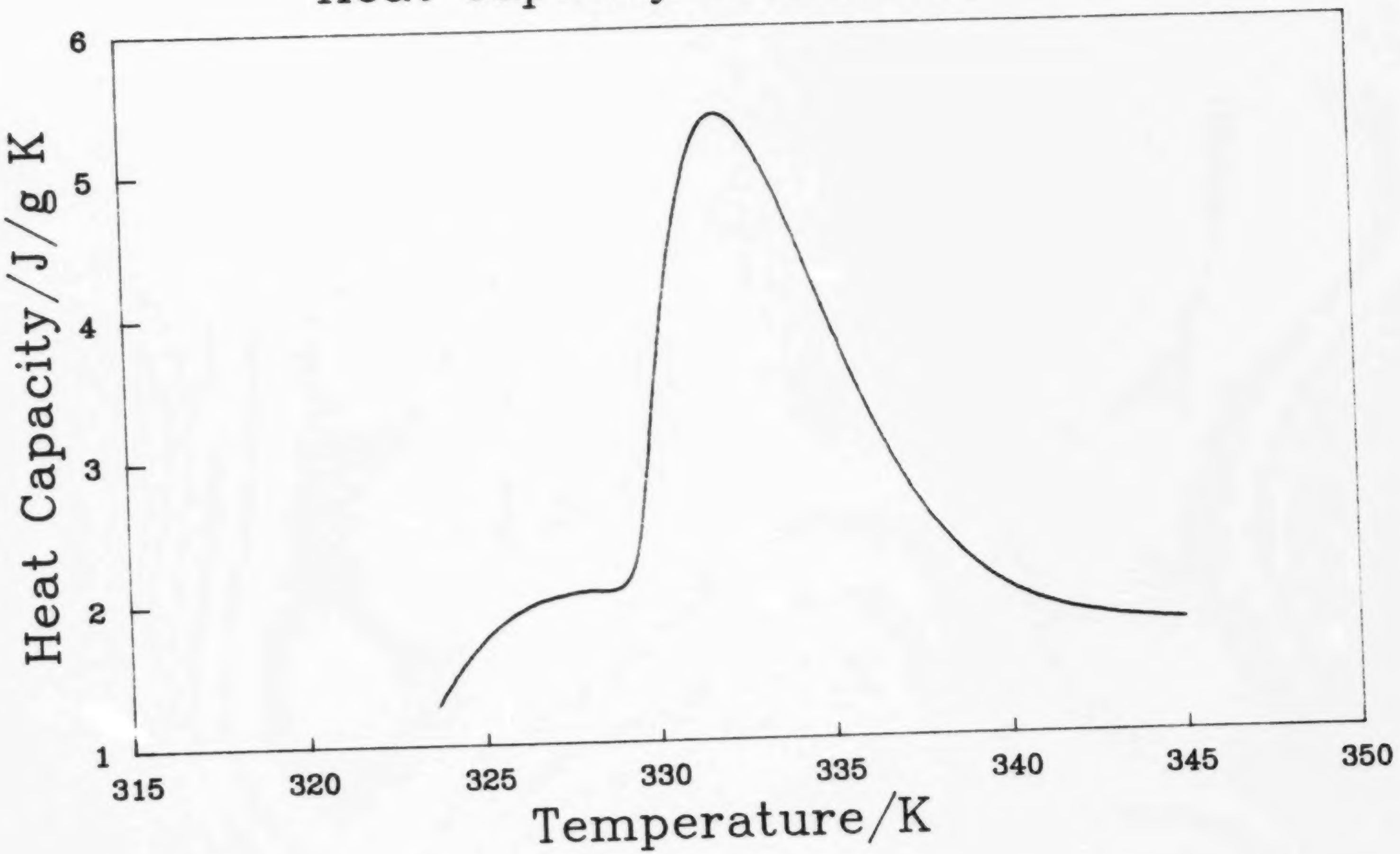


Figure 20

Heat Capacity of CuO doped AN

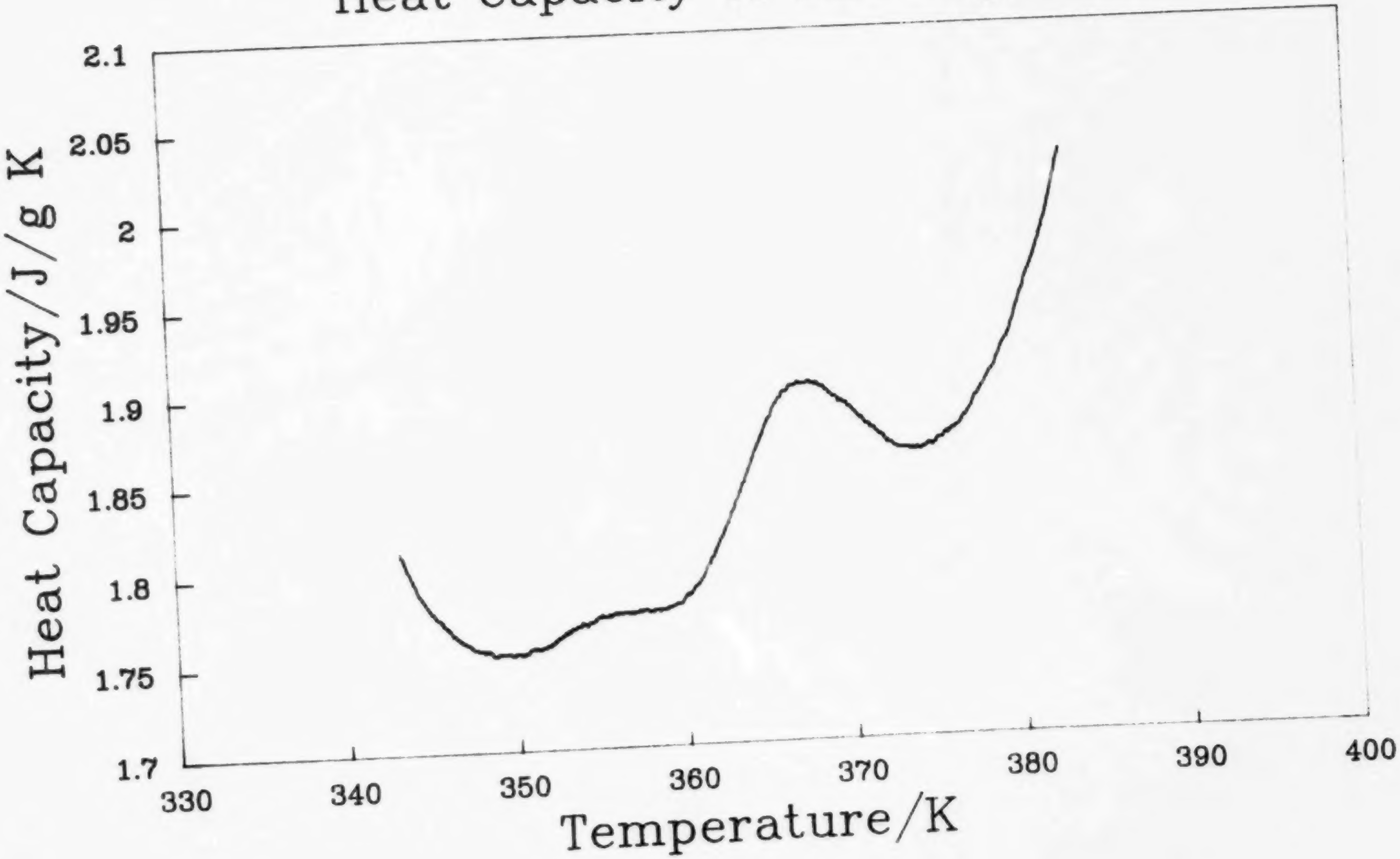


Figure 21

Heat Capacity of CuO doped AN

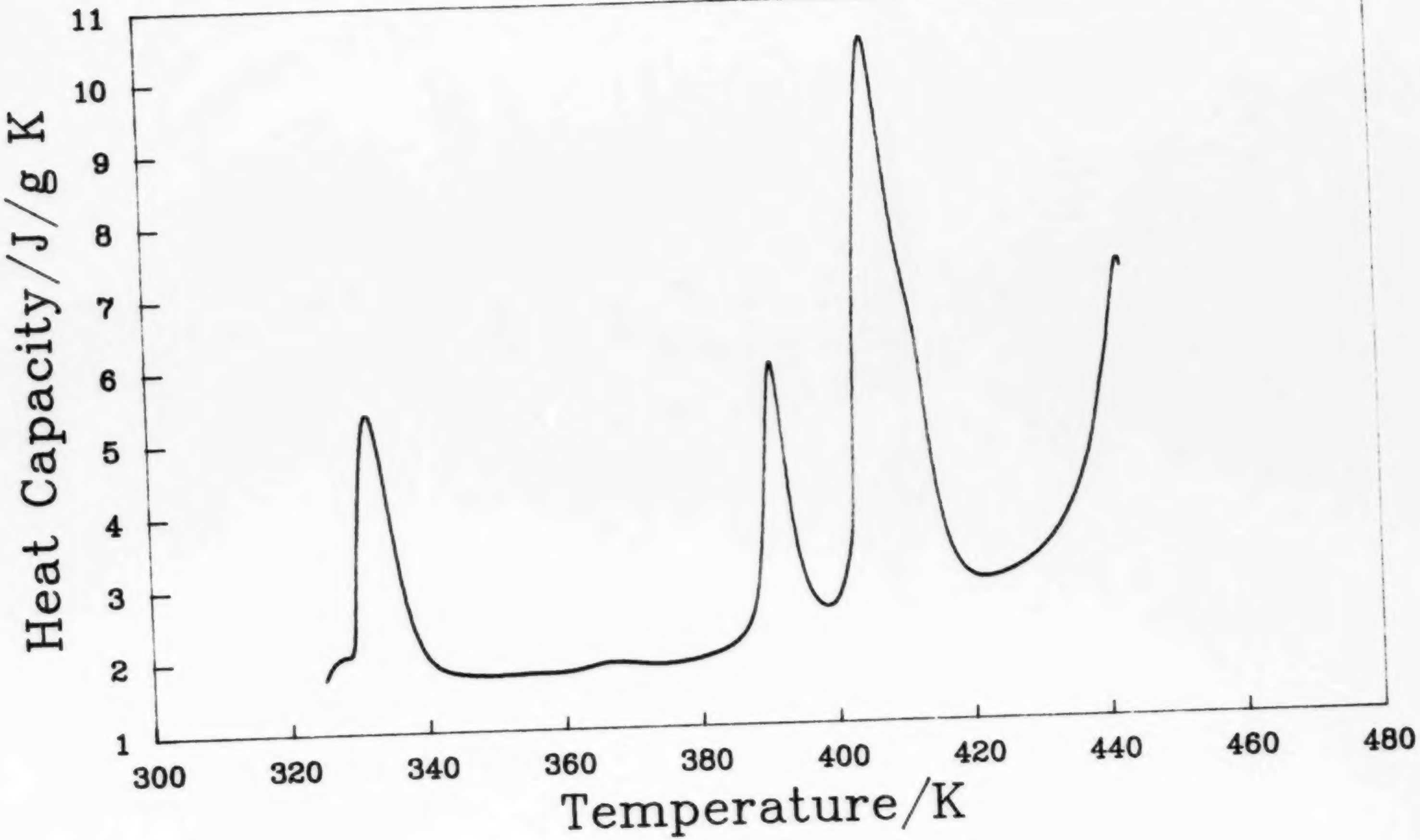


Figure 22

Heat Capacity of NiO doped AN

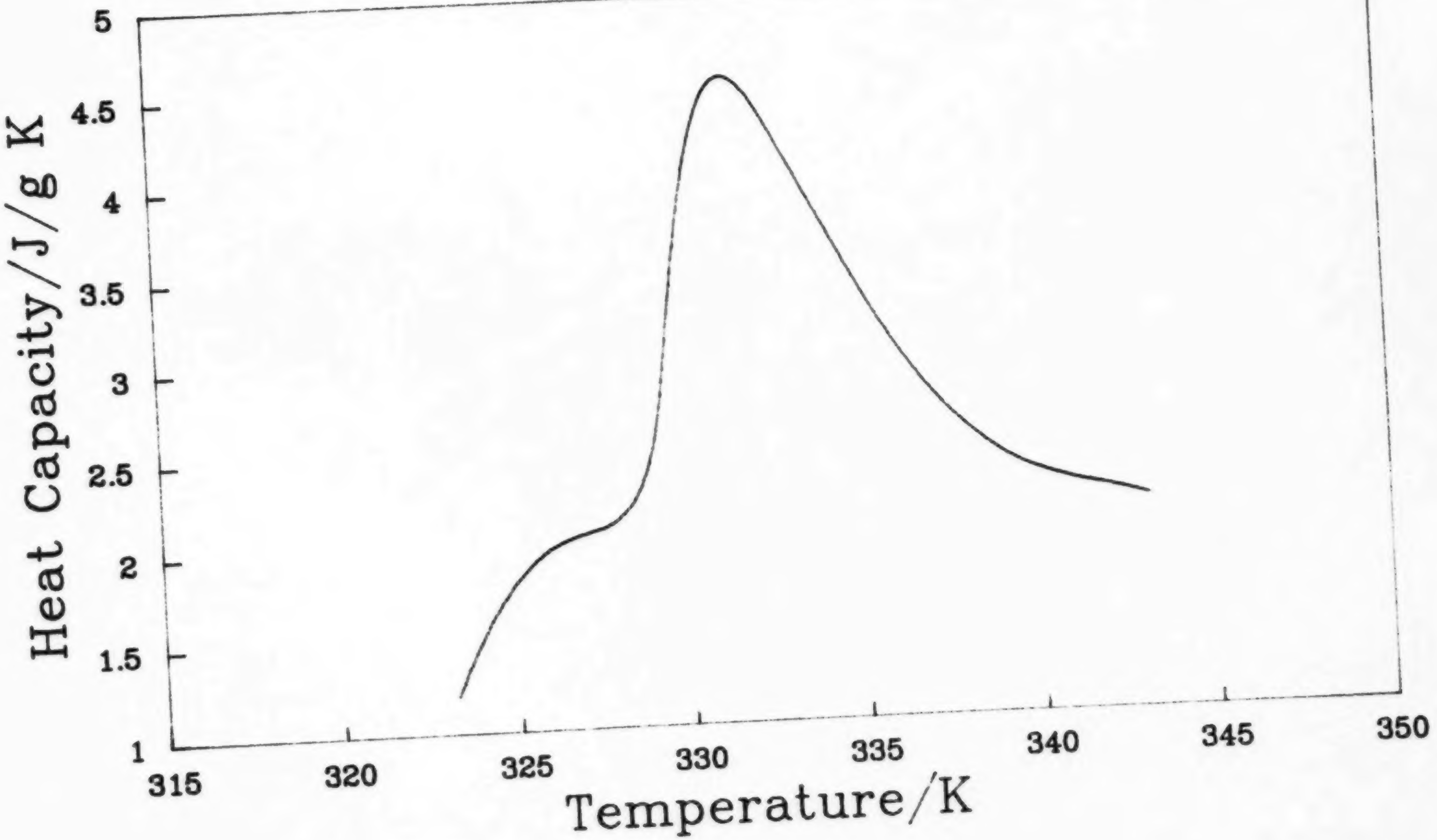


Figure 23

Heat Capacity of NiO doped AN

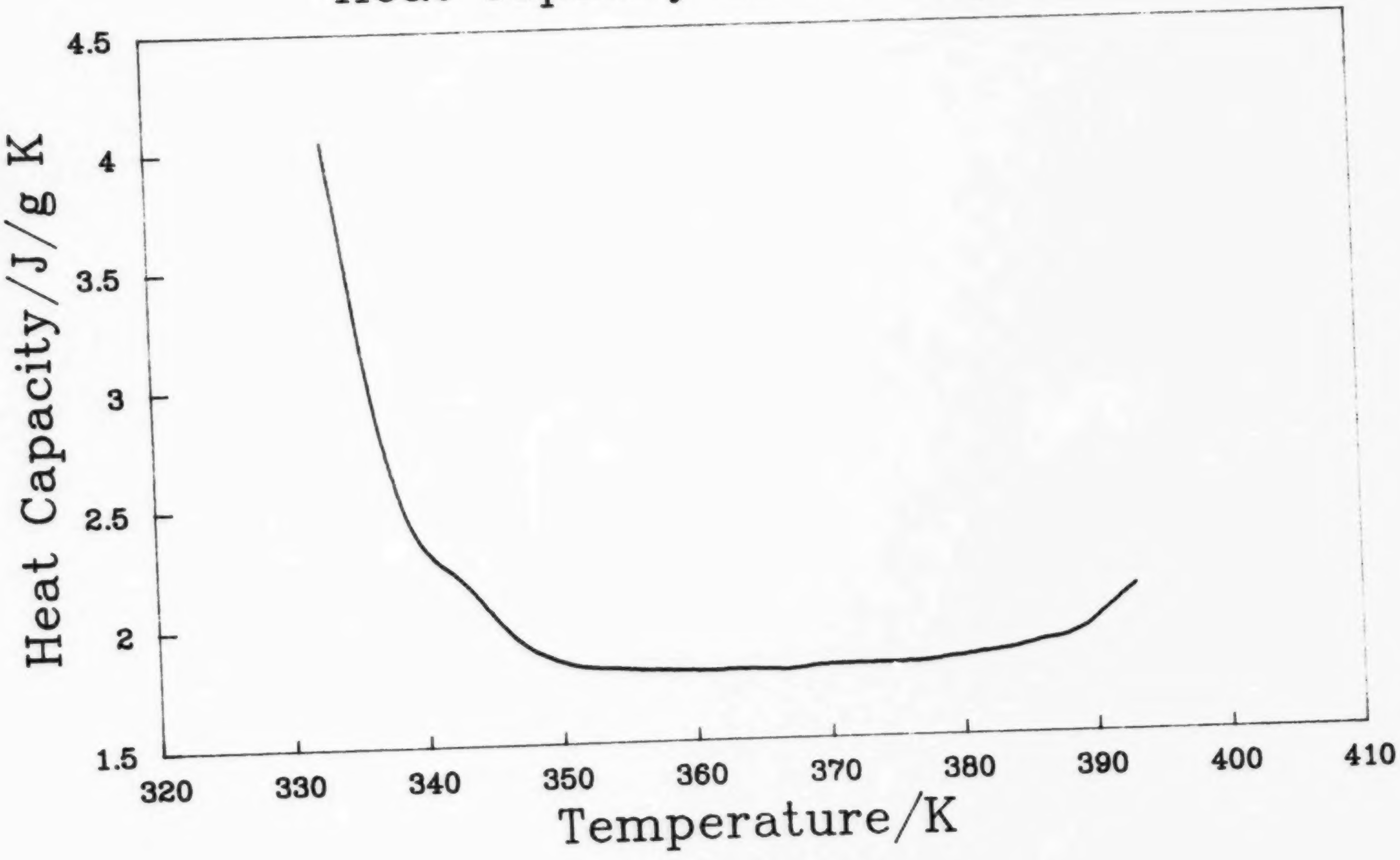
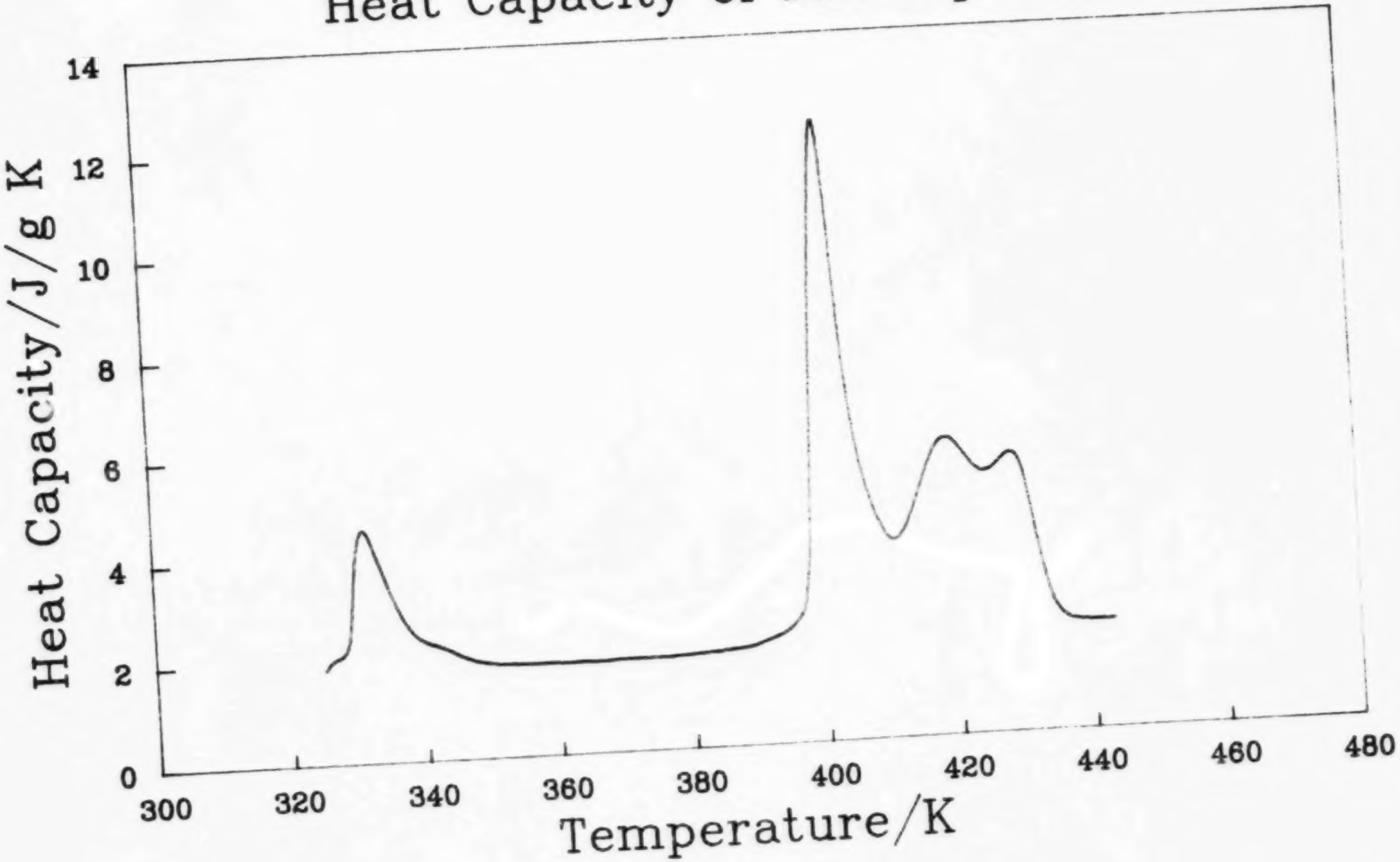


Figure 24

Heat Capacity of NiO doped AN